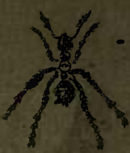
CHAPTERS IN POPULAR NATURAL HISTORY



SIR JOHN LUBBOCK, BART.

NATIONAL SOCIETY'S DEPOSITORY, WESTMINSTER

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E. A. Burke.

CHAPTERS

IN

POPULAR NATURAL HISTORY.

BY

SIR JOHN LUBBOCK, BART., M.P., F.R.S.,

D.C.L., LL.D., PRES. LINN. SOC., ETC., ETC., ETC.

ARRANGED AS AN ADVANCED READING BOOK FOR USE IN ELEMENTARY AND HIGHER SCHOOLS.

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PREFACE.

THE National Society has done me the honour to propose to republish parts of some of my Natural History Lectures adapted as a Reading Book.

Those who may wish to pursue the subjects further, I would refer to my "Origin and Metamorphoses of Insects" (Macmillan and Co.), "British Wild Flowers," &c. (Macmillan and Co.), "Scientific Lectures" (Macmillan and Co.), and "Ants, Bees, and Wasps" (Paul, Trench, and Co.).

I am greatly indebted to my publishers for their courtesy in allowing me to reprint here part of the above-mentioned works.

I have also to thank Messrs. Paul, Trench, and Co., Messrs. Macmillan and Co., Messrs. Cassell and Co., and Messrs. Lovel Reeve and Co., for the use of various illustrations, which they have been so good as to place at my disposal.

HIGH ELMS, DOWN, KENT.
December, 1882.

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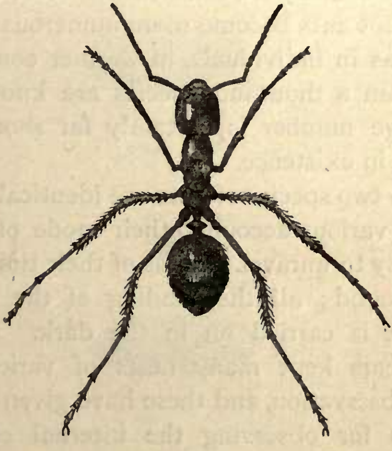


Fig. 1.—The Slave-making Ant.

SECTION I.—ANTS.

I.

1. There is no animal or plant which would not well repay long and careful study. Yet all are by no means equally interesting. Some specially de-

serve attention from their utility to man, some from their power of inflicting injury. Among insects there are few, if any, whose habits are more interesting than those of **Ants.** They live in large communities: they build houses; they make roads; some of them, as we shall presently see, keep other insects, just as we keep cows; and some of them even have slaves.

In this country we have rather more than thirty kinds; but ants become more numerous in species, as well as in individuals, in warmer countries, and more than a thousand species are known. Even this large number is certainly far short of those actually in existence.

2. No two species of ants are identical in habits; and, on various accounts, their mode of life is far from easy to unravel. Most of their time is passed underground; all the tending of the young, for instance, is carried on in the dark. I have for some years kept many nests of various species under observation, and these have given me special facilities for observing the internal economy of ant life. Another main difference between my observations and those of previous naturalists has consisted in the careful record of the actions of individual ants. The most convenient mode of marking them was, I found, a small dab of paint on the back.

3. The life of an ant falls into four well-marked periods—those of the **egg**, of the **larva** or grub

(fig. 2, *a a′*), of the **pupa** or chrysalis (fig. 2, *b b′*) and of the perfect insect or **imago**. The eggs are white or yellowish, and somewhat elongated.

Fig. 2.—Larva (*a a′*), Chrysalis (*b b′*), and Cocoon (*c c′*) of the Horse Ant. Magnified and nat. size.

They are generally said to be hatched about fifteen days after being laid, but those observed by me have taken a month or six weeks.

The larvæ or grubs of ants, like those of bees and wasps, are small, white, legless creatures, somewhat conical in form, narrowing towards the head. They are carefully tended and fed, being carried about from chamber to chamber by the workers, probably in order to secure the most suitable amount of warmth and moisture. I have observed, also, that they are very often assorted according to age. It is sometimes very curious in my nests to see them arranged in groups according to size, so that they remind one of a school divided into five or six classes.

4. As regards the length of life of the larvæ, those which are born in the spring become full grown in a few weeks. In other cases the period is much longer. In certain species—the small yellow **Meadow Ant**, for instance—some of the larvæ live through the winter.

When full grown the larvæ turn into pupæ, sometimes naked (fig. 2, *b b′*), sometimes covered with a silken cocoon (fig. 2, *c c′*), constituting the so-called "ant-eggs." We do not yet understand why some larvæ spin cocoons, while others remain naked. As a general rule, the species which have a sting are naked, while those which have not are enveloped in a cocoon. There is, however, one species the larvæ of which sometimes spin

a cocoon, and sometimes remain naked. The reason for this difference is still quite unknown. After remaining some days in the pupa state they emerge as perfect insects. In many cases, however, they would perish in the attempt if they were not assisted ; and it is very pretty to see the older ants helping them to extricate themselves, carefully unfolding their legs and smoothing out their wings, with truly feminine tenderness and delicacy.

5. In the case of ants, as with other insects which pass through similar metamorphoses—such as bees, wasps, moths, butterflies, flies, beetles, &c.—the larval stage is the period of growth. During the chrysalis stage, though immense changes take place, and the organs of the perfect insect are more or less rapidly developed, no food is taken, and there is no addition to the size or weight.

The imago or perfect insect again takes food, but does not grow. The ant, like all the insects above named, is as large when it emerges from the pupa as it ever will be, though the abdomen of the females sometimes increases in size from the development of the eggs.

6. We have hitherto had very little information as to the length of life in ants in the imago, or perfect, state. So far, indeed, as the preparatory stages are concerned, there is little difficulty in approximately ascertaining the facts ; namely, that while in summer the larval condition lasts only a few

weeks, in some species, as in our small yellow Meadow Ants, the autumn larvæ remain with comparatively little change throughout the winter. It is much more difficult to ascertain the length of life of the perfect insects, on account of their gregarious habits, and the difficulty of recognising individual ants. I have found, however, as we shall presently see, that their life is much longer than has been generally supposed; and I have now two ants which are more than nine years old.

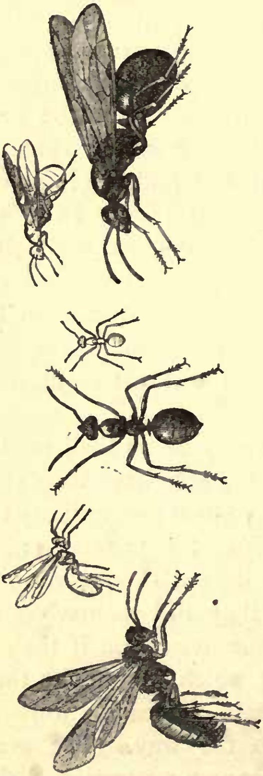
I have kept in captivity about half of our British species of ants, as well as a considerable number of foreign forms, and for the last few years have generally had from thirty to forty communities under observation.

7. Some ants have a sting; some bite with their jaws, and then squirt poison into the wound. Indeed, in some cases the poison is sufficiently strong itself to cause a wound. Moreover, some species have the power of ejecting their poison to a considerable distance. In Switzerland, after disturbing a nest of the **Horse Ant**, I have found that a hand held as much as 18 inches above the ants was covered with acid. But even when the poison is not thus fired, as it were, at the enemy from a distance, there are two cases in which the sting might be allowed to fall into disuse. Firstly, those species which fight with their mandibles might find it on the whole most convenient to inject the poison (as they do) into the wounds thus created. Secondly, if

the poison itself is so intensified in virulence as to act through the skin, a piercing instrument would be of comparatively small advantage. I was amused one day by watching some specimens of a small species of ant, which were feeding on some drops of honey. Some ants of a larger kind were anxious to share the feast, but the moment one approached, the little ones simply threatened them with the tip of their tail, and the large ones immediately beat a hasty retreat. In this case the comparatively large kind could certainly have had nothing to fear from physical violence on the part of the little ones. Mere contact with the poison, however, appeared to cause them considerable pain; and generally the threat alone was sufficient to cause a retreat.

8. However this may be, in their modes of fighting different species of ants have their several peculiarities. Some are much less military than others. *Myrmecina Latreillii*, for instance, never attack, and scarcely even defend themselves. Their skin is very hard, and they roll themselves into a ball, not defending themselves even if their nest is invaded; to prevent which they make the entrances small, and often station at each a worker, who uses her head to stop the way. The scent of this species is also, perhaps, a protection. *Tetramorium cæspitum* has the habit of feigning death. This species, however, does not roll itself up, but merely applies its legs and antennæ closely to the body.

Formica rufa (fig. 3), the common **Horse Ant,** attacks in serried masses, seldom sending out de-



Female. Worker. Male.

Fig. 3.—The Horse Ant, Male, Female, and Worker. Nat. size and magnified.

tachments, while single ants scarcely ever make individual attacks. They rarely pursue a flying foe, but give no quarter, killing as many enemies as

possible, and never hesitating to sacrifice themselves for the common good.

9. *Formica sanguinea*, on the contrary, though very like the Horse Ant in appearance, is very different in habits. It is a slave-making species, and in their military expeditions, they attempt rather to terrify than to kill. Indeed, when invading a nest, they do not attack the flying inhabitants unless these are attempting to carry off pupæ, in which case the *F. sanguinea* force them to abandon the pupæ. When fighting, they attempt to crush their enemies with their mandibles.

10. *Formica exsecta* is a delicate, but very active species. They also advance in serried masses, but in close quarters they bite right and left, dancing about to avoid being bitten themselves. When fighting with larger species they spring on to their backs, and then seize them by the neck or by an antenna. They also have the instinct of acting together, three or four seizing an enemy at once, and then pulling different ways, so that she on her part cannot get at any one of her foes. One of them then jumps on her back and cuts, or rather saws, off her head. In battles between this ant and the much larger *F. pratensis*, many of the *F. exsecta* may be seen on the backs of the *F. pratensis*, sawing off their heads from behind.

11. The ants of the different species of *Lasius* make up in numbers what they want in strength. Several of them seize an enemy at once, one by

each of her legs or antennæ, and when they have once taken hold they will suffer themselves to be cut in pieces rather than leave go.

The **Amazon Ant**, which, like *Formica sanguinea*, is a slave-making species, has a mode of combat almost peculiar to herself. The jaws are very powerful and pointed. If attacked—if, for instance, another ant seizes her by a leg—she at once takes her enemy's head into her jaws, which generally makes her quit her hold. If she does not, the ant closes her mandibles, so that the points pierce the brain of her enemy, paralysing the nervous system. The victim falls in convulsions, setting free her terrible foe. In this manner a comparatively small force will fearlessly attack much larger armies of other species, and suffer themselves scarcely any loss.

Fig. 4.—Mexican Honey Ant.
Nat. size and magnified.

II.

1. Under ordinary circumstances an ants' nest, like a beehive, contains three kinds of individuals (fig. 3):

workers or imperfect females (which constitute the great majority), males, and perfect females. There are often, however, several queens in an ants' nest; while, as we all know, there is never more than one queen mother in a hive. The queens of ants are provided with wings, but after a single flight they tear them off, and do not again quit the nest. In addition to the ordinary workers, there is in some species a second, or rather a third, form of female. In almost any ants' nest we may see that the workers differ more or less in size. The amount of difference, however, depends upon the species. In the small brown **Garden Ant**, the workers are, for instance, much more uniform than in the little yellow **Meadow Ant**, or in the **Harvesting Ant**, where some of them are much more than twice as large as others. But in certain ants there are differences still more remarkable. Thus, in a Mexican species (fig. 4), besides the common workers, which have the form of ordinary neuter ants, there are certain others in which the abdomen is swollen into an immense sphere. These individuals are very inactive, and serve principally as living honey-jars. They receive the honey from the foragers, retain it unaltered in their crop, and feed their companions when fresh food falls short. In another kind, very common in Southern Europe, there are also two distinct forms without any intermediate gradations; one with heads of the usual proportion, and a second with immense heads

provided with very large jaws. The large-headed individuals are generally supposed to act as soldiers, and the size of the head enables the muscles which move the jaws to be of unusual dimensions; but the little workers are also very pugnacious.

2. Bates tells us that in the marching columns of *Eciton* (a kind of South American ant) the large-headed workers "all trotted along empty-handed and outside the column, at pretty regular intervals from each other, like subaltern officers in a marching regiment . . . I did not see them change their position, or take any notice of their small-headed comrades;" and he says that if the column was disturbed they appeared less pugnacious than the others.

In the **Sauba Ant** of South America there are five distinct kinds of individuals. I have figured two (fig. 5). They are sisters, and of the same age, but so unlike one another that one would hardly suppose they belonged to the same species. No doubt they perform different duties. It has been supposed that the large ones act as soldiers, but the reason for the difference between the different kinds of workers is still uncertain.

3. For some little time after arriving at maturity, ants devote themselves exclusively to the care of the larvæ and pupæ, and take no share in the defence of the nest or other out-of-door work until they are some days old. This seems natural, because at first their skin is comparatively soft; and it

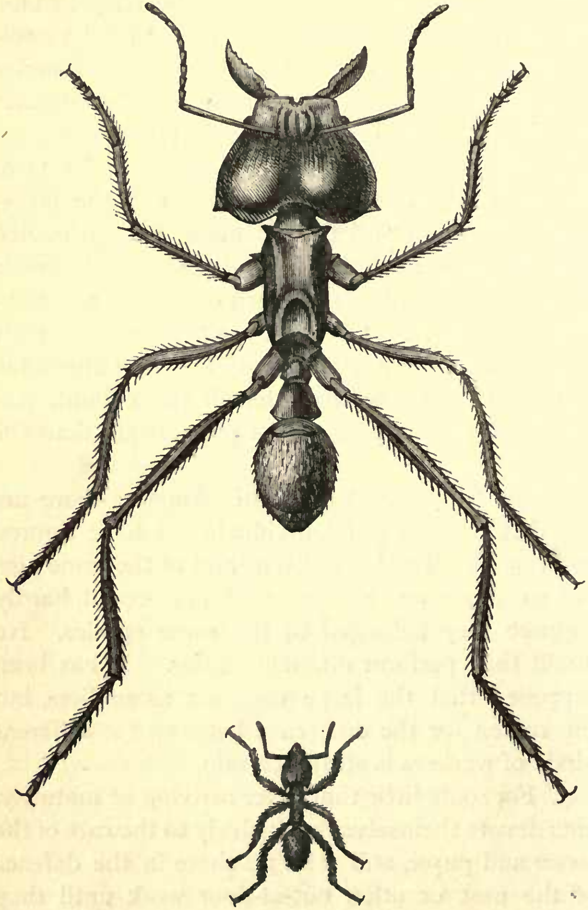


Fig. 5.—The Sauba Ant (*Oecodoma cephalotes*).
Two sisters. Magnified four times.

would clearly be undesirable for them to undertake rough work or run into danger until their armour had had time to harden. There are, however, reasons for thinking that the division of labour is carried still further. I do not allude merely to those cases in which there are completely different kinds of workers, but also to the ordinary workers. In the yellow **Meadow Ant**, for instance, it seems probable that the duties of the small workers are rather different to those of the large ones, though no such division of labour has yet been detected. I have myself made some further observations pointing in the same direction.

III.

1. The nests of ants may be divided into several classes. Some species, our common **Horse Ant** for instance, collect large quantities of materials, such as bits of stick, fir leaves, &c., which they heap up into conical masses. Some construct their nests of earth, the cells being partly above, partly below, the natural level. Some are entirely underground, others eat into the trunks of old trees.

In some cases the nests are very extensive. Bates mentions that while he was at Pará an attempt was made to destroy a nest of the **Sauba Ants** by blowing into it the fumes of sulphur, and he saw the smoke issue from a great number of holes, some of them not less than 70 yards apart.

2. A community of ants must not be confused with an ant hill in the ordinary sense. Very often, indeed, a community has only one dwelling, and in most species seldom more than three or four. Some, however, form numerous colonies. M. Forel even found a case in which one community had no less than 200 colonies, and occupied a circular space with a radius of nearly 200 yards. Within this area they had destroyed almost all the other ants. In these cases the number of ants thus associated together must have been enormous. Even

in single nests Forel estimates the numbers at from 5,000 to 500,000.

Ants also make for themselves roads. These are not merely worn by the continued passage of the ants, as has been supposed; but are actually prepared by the ants, rather, however, by the removal of obstacles than by any actual construction. In some cases these roadways are arched over with earth, so as to form covered ways. In others, the ants excavate regular subterranean tunnels, sometimes of considerable length.

3. The food of ants consists of insects, great numbers of which they destroy; of honey, honey-dew, and fruit—indeed, scarcely any animal or sweet substance comes amiss to them. Some species—such, for instance, as the small brown **Garden Ant**—ascend bushes in search of **aphides** (fig. 6). The ant then taps the **aphis** gently with her antennæ, and the aphis emits a drop of sweet fluid, which the ant drinks. Sometimes the ants even build covered ways up to and over the aphides, which, moreover, they protect from the attacks of other insects. Our English ants do not store up provision for the winter; indeed, their food is not of a nature which would admit of this.

4. Ants have many enemies. They themselves, and still more their young, are a favourite food of many animals. They are attacked also by numerous parasites. If a nest of the brown ant is disturbed at any time during the summer, some

small flies may probably be seen hovering over the nest, and every now and then making a dash at

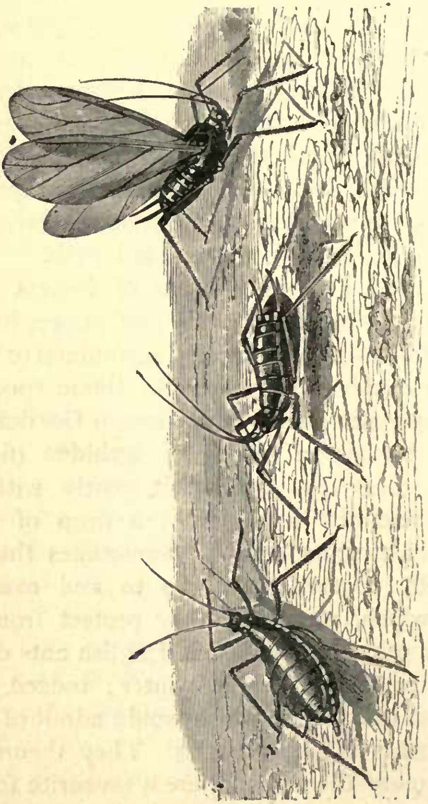


Fig. 6.—The Rose-feeding Aphis (*Aphis Rosæ*).

some particular ant. These flies lay their eggs on the ants, inside which the larvæ live. Other

species of the genus are in the same way parasitic on bees. Ants are also sometimes attacked by mites. On one occasion I observed that one of my ants had a mite attached to the underside of its head. The mite, which maintained itself for more than three months in the same position, was almost as large as the head of the ant. The ant could not remove it herself. Being a queen, she did not come out of the nest, so that I could not do it for her; and none of her own companions thought of performing this kind office.

5. In character the different species of ants differ very much from one another. *F. fusca*, the one which is pre-eminently the "**Slave**" **Ant**, is, as might be expected, extremely timid; while the nearly allied *F. cinerea* has, on the contrary, a considerable amount of individual audacity. *F. rufa*, the **Horse Ant**, is, according to M. Forel, especially characterised by the want of individual initiative, and always moves in troops; he also regards the genus *Formica* as the most brilliant, though others excel it in other respects—as, for instance, in the sharpness of their senses. *F. pratensis* worries its slain enemies; *F. sanguinea* never does so. The **Amazon Ant** is, perhaps, the bravest of all. If a single individual finds herself surrounded by enemies she never attempts to fly, as any other ant would, but transfixes her opponents one after another, springing right and left with great agility, till at length she succumbs, over-

powered by numbers. *Myrmica scabrinodis* is cowardly and thievish; during wars among the larger species they haunt the battle-fields and devour the dead. *Tetramorium* is said to be very greedy; *Myrmecina* very phlegmatic.

6. In industry ants are not surpassed even by bees and wasps. They work all day, and in warm weather, if need be, even at night too. I once watched an ant from six in the morning till a quarter to ten at night, and she worked without intermission the whole time. I had put her to a saucer containing larvæ, and in this time she carried off no less than 187 to the nest. I kept another ant which I employed in my experiments, under observation several days. When I had to leave the house, and again when I went to bed at night, I kept her shut up in a small bottle, but the moment I let her out she began to work again. On one occasion I was away from home for a week. On my return I took her out of the bottle, placing her on a little heap of larvæ about three feet from the nest. Under these circumstances I certainly did not expect her to return. However, though she had thus been six days in confinement, the brave little creature immediately picked up a larva, carried it off to the nest, and after half an hour's rest returned for another.

7. Our countryman Gould noticed certain "amusements" or "sportive exercises" which he had observed among ants. Huber also mentions

scenes which he had witnessed on the surface of ant hills, and which, he says, "I dare not qualify with the title gymnastic, although they bear a close resemblance to scenes of that kind." The ants raised themselves on their hind legs, caressed one another with their antennæ, engaged in mock combats, and almost seemed to be playing at "hide and seek." Forel entirely confirms Huber's statements, though he was at first incredulous.

8. Lastly, I may observe that ants are very cleanly animals, and assist one another in this respect. I have often seen them licking one another. Those, moreover, which I painted for facility of recognition were gradually cleaned by their friends.

Though ants have not influenced the present condition of the vegetable kingdom to the same extent as bees, yet they also have had a very considerable effect upon it in many ways.

Our European ants do not strip plants of their leaves. In the tropics, on the contrary, some species do much damage in this manner.

9. There are, of course, many cases in which the action of ants is very beneficial to plants. They kill off a great number of small caterpillars and other insects. Forel found in one large nest that more than 28 dead insects were brought in per minute, which would give during the period of greatest energy more than 100,000 insects destroyed in a day by the inhabitants of one nest alone.

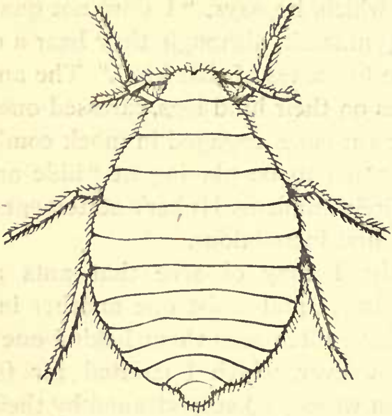


Fig. 7.—Root-feeding Aphis.

IV.

1. As already mentioned, none of our northern ants store up grain, and hence there has been much discussion as to the well-known passage of Solomon. I have, however, observed that the small brown ants sometimes carry seeds of the violet into their nests, but for what purpose is not clear. It is, however, now a well-established fact that more than one species of southern ants do collect seeds of various kinds. The fact, of course, has long been known in those regions.

2. A **Texan Ant** is also a harvesting species, storing up especially the grains of the so-called "ant-

rice" and of a grass. These ants clear disks, 10 or 12 feet in diameter, round the entrance to their nest —a work of no small labour in the rich soil, and under the hot sun, of Texas. I say "clear" disks, but some, though not all, of these disks are occupied, especially round the edge, by a growth of ant-rice. It seems evident that the disks are kept carefully clean, that the ant-rice alone is permitted to grow on them, and that the produce of this crop is carefully harvested; but it is possible that the ant-rice sows itself, and is not actually cultivated by the ants. I have myself observed in Algeria, that certain plants are allowed by the ants to grow on their nests while others are destroyed.

3. The relations existing between ants and other animals are even more interesting than their relations with plants. As a general rule—not, however, without many remarkable exceptions—they may be said to be those of deadly hostility.

Though honey is the principal food of ants they are very fond of meat, and in their wild state ants destroy large numbers of other insects. Our English ants generally go out hunting alone, but many of the species living in hotter climates hunt in packs, or even in troops.

4. Savage has given a graphic account of the "**Driver**" **Ants** of West Africa. They keep down, he says, "the more rapid increase of noxious insects and smaller reptiles; consume much dead animal matter, which would otherwise become

offensive, and thus vitiate the atmosphere; and often compel the inhabitants to keep their dwellings, towns, and their vicinity in a state of comparative cleanliness."

These ants will soon destroy even the largest animal if it is confined. In one case Savage saw them kill near his house a snake four feet long. Indeed, it is said that they have been known to destroy the great boa, when gorged with food and powerless. The natives even fancy that the python, after crushing its victim, does not venture to swallow it, until it has made a search, and is satisfied that there are no "**Drivers**" in the vicinity! It is very remarkable that these hunting ants are blind. They emerge, however, principally by night, and, like some of the blind hunting ants of Brazil, prefer to move under covered galleries, which they construct rapidly as they advance.

5. It has long been known that ants derive a very important part of their sustenance from the sweet juice excreted by aphides. The ants may be said, almost literally, to milk the aphides; for the aphides generally retain the secretion until the ants are ready to receive it. The ants stroke and caress the aphides with their antennæ, and the aphides then emit the sweet fluid. These insects, in fact, as has been over and over again observed, are the cows of the ants.

The different species of ants utilise different species of aphis. The common brown Garden Ant

devotes itself principally to the aphides (fig. 6) which frequent twigs and leaves; another kind to the aphides which live on the bark of trees; while the little yellow ant keeps flocks and herds of the aphides which feed on the roots of grasses (fig. 7).

6. As the honey of the aphides is more or less sticky, it is probably an advantage to the aphis that it should be removed. Nor is this the only service which ants render to them. They protect them from the attacks of enemies; and not unfrequently even build cowsheds of earth over them. The **Yellow Ants** collect the root-feeding species (fig. 7) in their nests, and tend them as carefully as their own young. But this is not all. The ants not only guard the mature aphides, which are useful; but also the eggs of the aphides, which of course, until they come to maturity, are quite useless.

7. I first met with these eggs in February, 1876, and found that the ants took great care of them, carrying them off to the lower chambers with the utmost haste when the nest was disturbed. I brought some home with me and put them near one of my own nests, when the ants carried them inside. That year I was unable to carry my observations further. In 1877 I again procured some of the same eggs, and offered them to my ants, who carried them into the nest, and in the course of March I had the satisfaction of seeing them hatch into young aphides.

8. When my eggs hatched I naturally thought that

the aphides belonged to one of the species usually found on the roots of plants in the nests of the ants. To my surprise, however, the young creatures made the best of their way out of the nest, and, indeed, were sometimes brought out by the ants themselves. In vain I tried them with roots of grass, &c.; they wandered uneasily about, and eventually died. Moreover, they did not in any way resemble the subterranean species. In 1878 I again attempted to rear these young aphides; but though I hatched a great many eggs I did not succeed. In 1879, however, I was more fortunate. The eggs commenced to hatch the first week in March. Near one of my nests, in which I had placed some of the eggs in question, was a glass containing living specimens of several species of plant commonly found on or around ants' nests. To this some of the young aphides were brought by the ants. Shortly afterwards I observed on a plant of daisy, in the angles of the leaves, some small aphides, very much resembling those from my nest, though we had not actually traced them continuously. They seemed thriving, and remained stationary on the daisy. Moreover, whether they had sprung from the black eggs or not, the ants evidently valued them, for they built up a wall of earth round and over them. So things remained throughout the summer; but on the 9th October I found that the aphides had laid some eggs exactly resembling those found in the ants' nests; and on

examining daisy-plants from outside, I found on many of them similar aphides, and more or less of the same eggs.

9. Our ants, then, though they may not perhaps lay up food for the winter, do more, for they keep during six months the eggs which will enable them to procure food during the following summer—a case of prudence unexampled in the animal kingdom.

The nests of our **Common Yellow Ant** contain in abundance four or five species of aphis, more than one of which appears to be as yet undescribed. In addition, however, to the insects belonging to this family, there are a large number of others which live habitually in ants' nests, so that we may truly say that our English ants possess a much greater variety of domestic animals than we do ourselves. Large nests of the **Horse Ant** sometimes contain at least a thousand of such guests; and I believe that the aphides in a nest of the little yellow ant would often be much more numerous. We now know of no less than 584 species of insects, which are habitually found in association with ants, and of which 542 are beetles.

10. The association of some of these insects with ants may be purely accidental and without significance. In some of them no doubt the bond of union is merely the selection of similar places of abode; in some few others the ants are victimized by parasites of which they cannot rid themselves.

Then there are some insects, such as the caterpillar of that beautiful beetle, the rosechafer, which find a congenial place of residence among the collection of bits of stick, &c., with which certain species of ants make their nests.

11. Another class of ant guests are those which reside with the ants actually in their galleries and chambers, but which the latter never touch. Of these the commonest in England are a species for which I have proposed the name **Beckia**. They

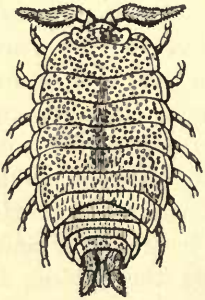


Fig. 8.—White Woodlouse (*Platyarthrus hoffmanseggii*). + 10.

are active bustling little beings, and I have kept hundreds, I may say thousands, in my nests. They run about in and out among the ants, keeping their antennæ in a perpetual state of vibration. Another very common species is a sort of white woodlouse (fig. 8). Both of these, from living constantly in the dark, have become blind; I say "have become,"

because their ancestors no doubt had eyes. In neither of these cases have I ever seen an ant take the slightest notice of either of these insects. One might almost imagine they had the cap of invisibility.

12. It is certain that the ants (if I may so say) sanction the residence of these insects in their nests. An unauthorised interloper would be at once killed. I have, therefore, ventured to suggest that these insects may, perhaps, act as scavengers.

In other cases the association is more close, and the ants take the greatest care of their guests.

It appears that many of these insects produce a secretion which serves as food for the ants. This is certainly the case, for instance, with a curious beetle (fig. 9), which is quite blind, and

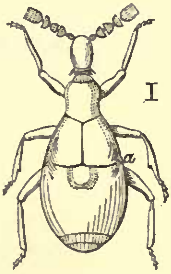


Fig. 9.--CLAVIGER.

appears to be absolutely dependent upon the ants. It even seems to have lost the power of feeding itself; at any rate, it is habitually fed by the ants,

who supply it with nourishment as they do one another. Müller saw the ants caressing the beetles with their antennæ. These beetles have certain tufts of hairs (fig. 9, *a*) at the base of the wingcases, and the ants take these tufts into their mouths and lick them, as well as the whole upper surface of the body, with apparently the greatest enjoyment.

Fig. 10.—The Slave Ant (*Formica fusca*).

V.

1. It is hardly necessary to say that, as a general rule, each species of Ant lives by itself. There are, however, some interesting exceptions. One little kind of ant is found exclusively in the nests of the much larger **Horse Ants**. We do not know what the relations between the two species are ; the small ones, however, follow the Horse Ants when they change their nest, running about among them and between their legs, tapping them inquisitively with their antennæ, and even sometimes climbing on to their backs, as if for a ride, while the large ants seem to take little notice of them. They almost seem to be the dogs, or perhaps the cats, of the ants. Another small species, which makes its chambers and galleries in the walls of the nests of larger

species, is the bitter enemy of its hosts. The latter cannot get at them, because they are too large to enter the galleries. The little ones, therefore, are quite safe, and, as it appears, make incursions into the nurseries of the larger ant, and carry off the larvæ as food. It is as if we had small dwarfs, about 18 inches to 2 feet long, harbouring in the walls of our houses, and every now and then carrying off some of our children into their horrid dens.

2. Most ants, indeed, will carry off the larvæ and pupæ of others if they get a chance; and this explains, or at any rate throws some light upon, that most remarkable phenomenon, the existence of slavery among ants. If you place a number of larvæ and pupæ in front of a nest of the **Horse Ant**, for instance, they are soon carried off; and those which are not immediately required for food remain alive for some time, and are even fed by their captors.

3. Both the Horse Ant and the Slave Ant are abundant species, and it must not unfrequently occur that the former, being pressed for food, attack the latter and carry off some of their larvæ and pupæ. Under these circumstances it no doubt occasionally happens that the pupæ come to maturity in the nests of the Horse Ant, and it is said that nests are sometimes, though rarely, found in which, with the legitimate owners, there are a few *Formica fusca*. With the Horse Ant this is, however, a very rare

and exceptional phenomenon; but with an allied species, *F. sanguinea*, a species which exists in some of our southern counties and throughout Europe, it has become an established habit. The *F. sanguinea* make periodical expeditions, attack neighbouring nests, carrying off the larvæ and pupæ, selecting those which will produce workers. When the latter come to maturity they find themselves in a nest consisting partly of *F. sanguinea*, partly of their own species, the results of previous expeditions. They adapt themselves to circumstances, assist in the ordinary household duties, and, having no young of their own species, feed and tend those of the *F. sanguinea*. But though the *F. sanguinea* are thus aided by their slaves, or as they should rather perhaps be called, by their auxiliaries, they have not themselves lost the instinct of working. It seems not improbable that there is some division of functions between the two species, but we have as yet no distinct knowledge on this point; and at any rate the *F. sanguinea* can "do" for themselves and carry on a nest, if necessary, without slaves.

4. Another species, the **Amazon Ant** (*Polyergus rufescens*, fig. 1), is much more dependent on its slaves, being, indeed, almost entirely so.

For the knowledge of the existence of slavery among ants we are indebted to Huber, and I cannot resist quoting the passage in which he records his discovery :—

"On June 17, 1804," he says, "while walking in the environs of Geneva between four and five in the evening, I observed close at my feet, traversing the road, a legion of Amazon Ants. They moved in a body with considerable rapidity, and occupied a space of from eight to ten inches in length by three or four in breadth. In a few minutes they quitted the road, passed a thick hedge, and entered a pasture ground, where I followed them. They wound along the grass without straggling, and their column remained unbroken, notwithstanding the obstacles they had to surmount. At length they approached a nest inhabited by dark ash-coloured ants (*Formica fusca*, fig. 10), the dome of which rose above the grass, at a distance of twenty feet from the hedge. Some of its inhabitants were guarding the entrance, but, on the discovery of an approaching army, darted forth upon the advanced guard. The alarm spread at the same moment in the interior, and their companions came forth in numbers from their underground residence. The Amazon Ants, the bulk of whose army lay only at the distance of two paces, quickened their march to arrive at the foot of the ant-hill; the whole battalion, in an instant, fell upon and overthrew the ash-coloured ants, who, after a short but obstinate conflict, retired to the bottom of their nest. The Amazon Ants now ascended the hillock, collected in crowds on the summit, and took possession of the principal avenues, leaving some of their com-

panions to work an opening in the side of the ant-hill with their teeth. Success crowned their enterprise, and by the newly-made breach the remainder of the army entered. Their sojourn was, however, of short duration, for in three or four minutes they returned by the same apertures which gave them entrance, each bearing off in its jaws a larva or a pupa."

5. The expeditions generally start in the afternoon, and are from 100 to 2,000 strong.

The **Amazon Ant** presents a striking lesson of the degrading tendency of slavery, for these ants have become entirely dependent on their slaves. Even their bodily structure has undergone a change: the mandibles have lost their teeth and have become mere nippers, deadly weapons indeed, but useless except in war. They have lost the greater part of their instincts: their art—that is, the power of building; their domestic habits, for they show no care for their own young, all this being done by the slaves; their industry—for they take no part in providing the daily supplies. If the colony changes the situation of its nest the mistresses are all carried by the slaves on their backs to the new one; nay, they have even lost the habit of feeding. Huber placed 30 of them with some larvæ and pupæ and a supply of honey in a box. "At first," he says, "they appeared to pay some little attention to the larvæ, they carried them here and there, but presently replaced them. More than one-half of the

Amazons died of hunger in less than two days; they had not even traced out a dwelling, and the few ants still in existence were languid and without strength. I commiserated their condition, and gave them one of their black companions. This individual, unassisted, established order, formed a chamber in the earth, gathered together the larvæ, extricated several young ants that were ready to quit the condition of pupæ, and preserved the life of the remaining Amazons."

6. This observation has been fully confirmed by other naturalists. However small the prison, however large the quantity of food, these stupid creatures will starve in the midst of plenty rather than feed themselves.

M. Forel was kind enough to send me a nest of the **Amazon Ants**, and I kept it under observation for more than four years. My specimens certainly never fed themselves, and when the community changed its nest, which they did several times, the mistresses were carried from the one to the other by the slaves. I was even able to observe one of their marauding expeditions, in which, however, the slaves took a part.

7. I do not doubt that, as Huber tells us, specimens if kept by themselves in a box would soon die of starvation, even if supplied with food. I have, however, kept isolated specimens for three months by giving them a slave for an hour or two a day to clean and feed them: under these circumstances

they remained in perfect health, while but for the slaves they would have perished in two or three days. Except the slave-making ants, and some of the beetles which live with ants, I know no case in nature of an animal having lost the instinct of feeding.

8. In the Amazon Ants, the so-called workers, though thus helpless and idle, are numerous, energetic, and in some respects even brilliant. In another slave-making ant, *Strongylognathus*, the workers are much less numerous and so weak that it is an unsolved problem how they contrive to make slaves. In the genus *Strongylognathus* there are two species, *S. huberi* and *S. testaceus*. *S. huberi*, which was discovered by Forel, very much resembles *Polyergus rufescens* in habits. They have sabre-like mandibles, like those of *Polyergus*, and their mode of fighting is similar, but they are much weaker insects; they make slaves of *Tetramorium cæspitum*, which they carry off as pupæ. In attacking the *Tetramoriums* they seize them by the head with their jaws just in the same way as *Polyergus*, but have not strength enough to pierce them as the latter do. Nevertheless, the *Tetramoriums* seem much afraid of them.

9. The other species, *Strongylognathus testaceus*, is even weaker than *S. huberi*, and their mode of life is still in many respects an enigma. They also keep the workers of *Tetramorium* in, so to say, a state of slavery, but how they procure the slaves is

still a mystery. They fight in the same manner as *Polyergus;* but are no match for the *Tetramoriums*, a courageous species, and one which lives in large communities. On one occasion Forel brought a nest of *Tetramorium* and put it down very near one of *Strongylognathus testaceus* with *Tetramorium* slaves. A battle at once commenced between the two communities. The *Strongylognathus* rushed boldly to the fight, but, though their side won the day, this was mainly due to the slaves. The *Strongylognathus* themselves were almost all killed; and though the energy of their attack seemed at first to disconcert their opponents, Forel assures us that they did not succeed in killing even a single *Tetramorium.* In fact, as he graphically observes, *Strongylognathus* is "a melancholy caricature" of *Polyergus*, and it seems almost impossible that by themselves they could successfully attack a nest of *Tetramorium.* Moreover, in *Strongylognathus*, the workers are comparatively few. Nevertheless, they are always found with the *Tetramoriums*, and in these mixed nests there are no males or females of *Tetramorium*, but only those of *Strongylognathus.* Again, the whole work of the nest is done by the slaves, though *Strongylognathus* has not, like *Polyergus*, entirely lost the power of feeding itself.

10. But if the economy of *Strongylognathus* is an enigma, that of *Anergates* is still more mysterious. It seems quite clear that *Anergates* cannot procure

its slaves, if such they are, by marauding expeditions like those of *Polyergus;* in the first place, because the *Anergates* are too few, and secondly, because they are too weak. The whole question is rendered more difficult because no larvæ or pupæ of *Tetramorium* have ever been found in the mixed nests. The community consisted of males and females of *Anergates*, accompanied and tended by workers of *Tetramorium cæspitum.* The *Anergates* are absolutely dependent upon their slaves, and cannot even feed themselves. The whole problem is, therefore, most puzzling and interesting.

11. These four genera offer us every gradation from lawless violence to contemptible parasitism. *Formica sanguinea*, which may be assumed to have comparatively recently taken to slave-making, has not as yet been materially affected.

The Amazon Ant (*Polyergus*), on the contrary, already illustrates the lowering tendency of slavery. They have lost their knowledge of art, their natural affection for their young, and even their instinct of feeding! They are, however, bold and powerful marauders.

In *Strongylognathus*, the enervating influence o slavery has gone further, and told even on the bodily strength. They are no longer able to capture their slaves in fair and open warfare. Still they retain a semblance of authority, and, when roused, will fight bravely, though in vain.

12. In *Anergates*, finally, we come to the last scene

of this sad history. We may safely conclude that in distant times their ancestors lived, as so many ants do now, partly by hunting, partly on honey; that by degrees they became bold marauders, and gradually took to keeping slaves; that for a time they maintained their strength and agility, though losing by degrees their real independence, their arts, and even many of their instincts; that gradually even their bodily force dwindled away under the enervating influence to which they had subjected themselves, until they sank to their present degraded condition—weak in body and mind, few in numbers, and apparently nearly extinct, the miserable representatives of far superior ancestors, maintaining a precarious existence as contemptible parasites of their former slaves.

13. But putting these slave-making ants on one side, we find in the different species of ants different conditions of life, curiously answering to the earlier stages of human progress. For instance, some species, such as *Formica fusca*, live principally on the produce of the chase; for though they feed partly on the honey-dew of aphides, they have not domesticated these insects. These ants probably retain the habits once common to all ants. They resemble the lower races of men, who subsist mainly by hunting. Like them they frequent woods and wilds, live in comparatively small communities, and the instincts of collective action are but little developed among them. They hunt singly, and their

battles are single combats, like those of the Homeric heroes. Such species as the yellow **Meadow Ant** represent a distinctly higher type of social life; they show more skill in architecture, may literally be said to have domesticated certain species of aphides, and their condition may be compared to the pastoral stage of human progress—to the races which live on the produce of their flocks and herds. Their communities are more numerous; they act much more in concert; their battles are not mere single combats, for they know how to act in combination. I am disposed to hazard the conjecture that they will gradually exterminate the mere hunting species, just as savages disappear before more advanced races. Lastly, the agricultural nations may be compared with the harvesting ants.

Thus there seem to be three principal types, offering a curious analogy to the three great phases—the hunting, pastoral, and agricultural stages—in the history of human development.

VI.

1. The behaviour of ants to one another differs much according to circumstances; whether, for instance, they are alone, or supported by friends. An ant which would run away in the first case will defend herself bravely in the second.

On one occasion several ants belonging to one of my nests were feeding on some honey spread on a slip of glass. One of them had got thoroughly entangled in it. I took her and put her down just in front of another individual belonging to the same nest, and close by I placed a drop of honey. The ant devoted herself to the honey and entirely neglected her friend, whom she left to perish. I then chloroformed one, and put her on the board among her friends. Several touched her, but from 12 to 2.30 P.M. none took any particular notice of her.

2. On the other hand, I have only on one occasion seen a living ant expelled from her nest. I observed (April 23, 1880) an ant carrying another belonging to the same community away from the nest. The condemned ant made a very feeble resistance. The first ant carried her burthen hither and thither for some time, evidently trying to get away from the nest, which was enclosed by a barrier of fur. After

watching for some time I provided the ant with a paper bridge, up which she immediately went, dropped her victim on the far side, and returned home. Could this have been a case in which an aged or invalid ant was being expelled from the nest?

3. In order to test the affection of ants belonging to the same nest for one another, I tried the following experiments. I took six ants from one of my nests, imprisoned them in a small bottle, one end of which was covered with a layer of muslin. I then put the muslin close to the door of the nest. The muslin was of open texture, the meshes, however, being sufficiently small to prevent the ants from escaping. They could, however, not only see one another, but communicate freely with their antennæ. We now watched to see whether the prisoners would be tended or fed by their friends. We could not, however, observe that the least notice was taken of them. The experiment, nevertheless, was less conclusive than could be wished, because they might have been fed at night or at some time when we were not looking. It struck me, therefore, that it would be interesting to treat some strangers also in the same manner.

4. On September 2, therefore, I put two ants from one of my nests into a bottle, the end of which was tied up with muslin as described, and laid it down close to the nest. In a second bottle I put two ants from another nest of the same species. The

ants which were at liberty took no notice of the bottle containing their imprisoned friends. The strangers in the other bottle, on the contrary, excited them considerably. The whole day one, two, or more ants stood sentry, as it were, over the bottle. In the evening no less than twelve were collected round it, a larger number than usually came out of the nest at any one time. The whole of the next two days, in the same way, there were several ants round the bottle containing the strangers; while, as far as we could see, no notice whatever was taken of the friends. On the 9th the ants had eaten through the muslin, and effected an entrance. We did not chance to be on the spot at the moment; but as I found two ants lying dead, one in the bottle and one just outside, I think there can be no doubt that the strangers were put to death. The friends throughout were quite neglected.

5. In one of my nests was an ant which had come into the world without antennæ. Never having previously met with such a case, I watched her with great interest; but she never appeared to leave the nest. At length one day I found her wandering about in an aimless sort of manner, and apparently not knowing her way at all. After a while she fell in with some specimens of the little yellow ant, who directly attacked her. I at once set myself to separate them; but owing either to the wounds she had received from her enemies

or to my rough though well-meant handling, or to both, she was evidently much wounded, and lay helplessly on the ground. After some time another ant from her nest came by. She examined the poor sufferer carefully, then picked her up gently and carried her away into the nest. It would have been difficult for any one who witnessed this scene to have denied to this ant the possession of humane feelings.

6. Again, on another occasion, I perceived a poor ant lying on her back and quite unable to move. The legs were in cramped attitudes, and the two antennæ rolled up in spirals. She was, of course, altogether unable to feed herself. After this I kept my eye on her. Several times I tried uncovering the part of the nest where she was. The other ants soon carried her into the shaded part. One day the ants were all out of the nest, probably for fresh air, and had collected together in a corner of the box; they had not, however, forgotten her, but had carried her with them. I took off the glass lid of the box, and after a while they returned as usual to the nest, taking her in again. The next day she was still alive, but shortly afterwards, notwithstanding all their care, she died.

At the present time I have two other ants perfectly crippled in a similar manner, so that they are quite unable to move, but they have been tended and fed by their companions, the one for five the other for four months.

7. In May, 1879, I gave a lecture on ants at the Royal Institution, and was anxious to exhibit a nest of the little yellow ant with the queen. While preparing the nest, on May 9, we accidentally crushed the queen. The ants, however, did not desert her, or drag her out as they do dead workers, but, on the contrary, carried her with them into the new nest, and subsequently into a larger one with which I supplied them, congregating round her, just as if she had been alive, for more than six weeks, when we lost sight of her.

8. In order to ascertain whether ants knew their fellows by any sign or pass-word, as has been suggested in the case of bees, I was anxious to see if they could recognise them when in a state of insensibility. I tried, therefore, the following experiments with some specimens of the little yellow ant:—

September 10, at 6 P.M., a number of these ants were out feeding on some honey, placed on one of my tables, and surrounded by a moat of water. I then took several ants, some belonging to the same nest and some from another, and intoxicated them. To do this I was obliged to put them for a few moments in spirit, for no ant would voluntarily drink more than was good for it. The sober ants took them up one by one. Their own friends they carried into the nest, while they threw the strangers into the ditch.

9. It seems clear, therefore, that even in a condi-

tion of insensibility ants are recognised by their friends.

It has been already shown that with ants, as with bees, while the utmost harmony reigns between those belonging to the same community, all others are enemies. I have elsewhere given ample proof that a strange ant is never tolerated in a community. This of course implies that all the bees or ants of a community have the power of recognising one another—a most surprising fact, when we consider their immense numbers. It is calculated that in a single hive there may be as many as 50,000 bees, and in the case of ants the numbers are still greater. In the large communities of ants it is probable that there may be as many as from 400,000 to 500,000 ants, and in other cases even these large numbers are exceeded.

10. If, however, a stranger is put among the ants of another nest she is at once attacked.

Moreover, we have not only to deal with the fact that ants know all their comrades, but that they recognise them even after a lengthened separation.

Huber mentions some ants which he had kept in captivity, and which had accidentally escaped, "met and recognised their former companions, fell to mutual caresses with their antennæ, took them up by their mandibles, and led them to their own nests; they came presently in a crowd to seek the fugitives under and about the artificial ant-hill, and even ventured to reach the bell-glass, where they

effected a complete desertion by carrying away successively all the ants they found there. In a few days the nest was depopulated. These ants had remained four months without any communication."

Forel, indeed, regards the movements observed by Huber as having indicated fear and surprise rather than affection; though he is quite disposed to believe, from his own observations, that ants would recognise one another after a separation of several months.

11. The above observation recorded by Huber was made casually, and he did not take any steps to test it by subsequent experiments. The fact, however, is of so much importance that I determined to make further observations on the subject. In the first place, I may repeat that I have satisfied myself by many experiments, that ants from one community introduced into another,—always, be it understood, of the same species,—are attacked, and either driven out or killed. It follows, therefore, that as within the nest the most complete harmony prevails—indeed, I have never seen a quarrel between sister ants—they must by some means recognise one another.

When we consider their immense numbers this is sufficiently surprising; but that they should recognise one another, as stated by Huber, after a separation of months, is still more astonishing.

I determined therefore to repeat and extend his observations.

VII.

1. Accordingly, on August 20, 1875, I divided a **colony of ants**, so that one half were in one nest, A, and the other half in another, B, and were kept entirely apart.

On October 3, I put into nest B a stranger and an old companion from nest A. They were marked with a spot of colour. One of the ants immediately flew at the stranger; of the friend they took no notice.

This experiment I repeated many times, and always with the same result.

2. I separated one of my colonies of ants into two halves on August 4, 1875, and kept them entirely apart. From time to time I put specimens from the one half back into the other. At first the friends were always amicably received, but after some months' separation they were occasionally attacked, as if some of the ants, perhaps the young ones, did not recognise them. Still they were never killed, or driven out of the nest, so that evidently when a mistake was made, it was soon recognised. No one who saw the different manner in which these ants and strangers were treated could have the slightest doubt that the former were recognised as friends and the latter as enemies

The last three were put back on May 14, 1877, that is to say, after a separation of a year and nine months, and yet they were amicably received, and evidently recognised as friends!

That ants and bees have a certain power of communication cannot be denied, but how far their powers reach is very doubtful.

3. Every one knows that if an ant or a bee in the course of her rambles has found a supply of food, a number of others will soon make their way to the store. This, however, does not necessarily imply any power of describing localities. A very simple sign would suffice, and very little intelligence is implied, if the other ants merely accompany their friend to the treasure which she has discovered. On the other hand, if the ant or bee can describe the locality, and send her friends to the food, the case is very different. This point, therefore, seemed to me very important; and I have made a number of observations bearing on it.

4. The following may be taken as a type of what happens under such circumstances. On June 12, 1874, I put an ant, belonging to a nest which I had kept two or three days without food, to some honey. She fed as usual, and then was returning to the nest, when she met some friends, whom she proceeded to feed. When she had thus distributed her stores, she returned alone to the honey, none of the rest coming with her. When she had a second time laid in a stock of food, she again in

the same way fed several ants on her way towards the nest; but this time five of those so fed returned with her to the honey. In due course these five would no doubt have brought others, and so the number at the honey would have increased.

5. Again, one rather cold day, when but few ants were out, I selected a specimen of an ant, belonging to a nest which I had brought back with me from Algeria. She was out hunting about 6 feet from home, and I placed before her a large dead bluebottle fly, which she at once began to drag to the nest. I then pinned the fly to a piece of cork, in a small box, so that no ant could see the fly until she had climbed up the side of the box. The ant struggled, of course in vain, to move the fly. She pulled first in one direction and then in another, but, finding her efforts fruitless, she at length started off back to the nest empty-handed. At this time there were no ants coming out of the nest. Probably there were some few others out hunting, but for at least a quarter of an hour no ant had left the nest. My ant entered the nest, but did not remain there; in less than a minute she emerged accompanied by seven friends. I never saw so many come out of that nest together before. In her excitement the first ant soon distanced her companions, who took the matter much more coolly, and had all the appearance of having come out reluctantly, or as if they had been asleep and were only half awake. The first ant ran on

ahead, going straight to the fly. The others followed slowly and with many meanderings; so slowly, indeed, that for 20 minutes the first ant was alone at the fly, trying in every way to move it. Finding this still impossible, she again returned to the nest, not chancing to meet any of her friends by the way. Again she emerged in less than a minute with eight friends, and hurried on to the fly. They were even less energetic than the first party; and when they found they had lost sight of their guide, they one and all returned to the nest. In the meantime several of the first detachment had found the fly, and one of them succeeded in detaching a leg, with which she returned in triumph to the nest, coming out again directly with four or five companions. These latter, with one exception, soon gave up the chase and returned to the nest. I do not think so much of this last case, because as the ant carried in a substantial piece of booty in the shape of the fly's leg, it is not surprising that some of her friends should have accompanied her on her return; but surely the other two cases indicate a distinct power of communication.

6. Lest, however, it should be supposed that the result was accidental, I determined to try it again. Accordingly on the following day I put another large dead fly before an ant belonging to the same nest, pinning it to a piece of cork as before. After trying in vain for ten minutes to move the fly, my ant started off home. At that time I could only

see two other ants of that species outside the nest. Yet in a few seconds, considerably less than a minute, she emerged with no less than 12 friends. As in the previous case, she ran on ahead, and they followed very slowly and by no means directly, taking, in fact, nearly half an hour to reach the fly. The first ant, after vainly labouring for about a quarter of an hour to move the fly, started off again to the nest. Meeting one of her friends on the way she conversed with her a little, then continued towards the nest, but, after going about a foot, changed her mind, and returned with her friend to the fly. After some minutes, during which two or three other ants came up, one of them detached a leg, which she carried off to the nest, coming out again almost immediately with six friends, one of whom, curiously enough, seemed to lead the way, tracing it, I presume, by scent. I then removed the pin, and they carried off the fly in triumph.

7. These experiments certainly seem to indicate the possession by ants of something approaching to language. It is impossible to doubt that the friends were brought out by the first ant; and as she returned empty-handed to the nest, the others cannot have been induced to follow her merely by observing her proceedings.

Ants, like many other insects, possess two kinds of eyes: a large compound eye on each side of the head, and three small ones, which are called "ocelli,"

arranged in a triangle on the forehead. We do not yet know how these eyes see, or whether the eyes and ocelli act in the same way.

But it seems clear that the image produced by the ocelli must be altogether different from the picture given by the compound eyes; and we may therefore reasonably conclude that the two organs have distinct functions.

8. The ocelli, or simple eyes, probably see in the same manner as ours do. That is to say, the lens throws an image on the back of the eye, which we call the retina. In that case they would see everything reversed, as we ourselves really do; though long practice has given us the right impression. The simple eye of insects thus resembles ours in this respect.

As regards the mode of vision of the compound eyes, there are two distinct theories. According to one, each facet takes in only a small portion of the field; while, according to the other, each facet acts as a separate eye.

9. This latter view has been maintained by many high authorities, but it is difficult to understand how so many images could be combined into one picture. Some insects have more than 20,000 facets on each side of their head. No ants, indeed, have so many, but in some there are not less than 1,000.

In fact, these, so far fortunate, insects realise the epigram of Plato—

Thou lookest on the stars, my love,
  Ah, would that I could be
Yon starry skies, with thousand eyes
  That I might look on thee!

But if an ant sees 1,000 queens at once, when only one is really present, this would seem to be a bewildering privilege, and the prevailing opinion among entomologists is, as already mentioned, that each facet only takes in a portion of the object.

10. But while it is difficult to understand how ants see, it is clear that they do see.

There could of course be little, if any, doubt, that bees are capable of distinguishing colours; and I have proved experimentally that this is the case.

Many eminent observers have regarded the antennæ of insects as auditory organs, and have brought forward strong evidence in favour of their view.

I have myself made experiments on **grasshoppers**, which convinced me that their antennæ serve as organs of hearing.

11. So far, however, as ants, bees, and wasps are concerned, the evidence is very conflicting.

I have never succeeded in satisfying myself that my **ants, bees,** or **wasps** heard any of the sounds with which I tried them. I have over and over again tested them with the loudest and shrillest noises I could make, using a penny pipe, a dog-whistle, a violin, as well as the most piercing and startling sounds I could produce with my own voice, but all without effect. At the same time, I care-

fully avoided inferring from this that they are really deaf, though it certainly seems that their range of hearing is very different from ours.

12. In order, if possible, to throw some light upon this interesting question, I made a variety of loud noises, including those produced by a complete set of tuning-forks, as near as possible to the ants while they were bringing food into the nest. In these cases the ants were moving steadily and in a most business-like manner, and any start or alteration of pace would have been at once apparent. I was never able, however, to perceive that they took the slightest notice of any of these sounds. Thinking, however, that they might, perhaps, be too much absorbed by the idea of the larvæ to take any notice of my interruptions, I took one or two ants at random and put them on a strip of paper, the two ends of which were supported by pins with their bases in water. The ants imprisoned under these circumstances wandered slowly backwards and forwards along the paper. As they did so, I tested them in the same manner as before, but was unable to perceive that they took the slightest notice of any sound which I was able to produce. I then took an ant belonging to one of the largest European species, and tethered her on a board to a pin by a delicate silk thread about 6 inches in length. After wandering about for a while, she stood still, and I then tried her in the same way; but, like the other ants, she took no notice whatever of the sounds.

It is of course possible, if not probable, that ants, even if deaf to sounds which we hear, may hear others to which we are deaf.

13. Having failed, therefore, in hearing them or making them hear me, I endeavoured to ascertain whether they could hear one another, but I was not able to do so.

It is, however, far from improbable that ants may produce sounds entirely beyond our range of hearing. Indeed, it is not impossible that insects may possess senses, or sensations, of which we can no more form an idea than we should have been able to conceive red or green if the human race had been blind. The human ear is sensitive to vibration, reaching at the outside to 38,000 in a second. The sensation of red is produced when 470 millions of millions of vibrations enter the eye in a similar time; but between these two numbers vibrations produce on us only the sensation of heat—we have no special organs of sense adapted to them. There is, however, no reason in the nature of things why this should be the case with other animals; and the problematical organs possessed by many of the lower forms may have relation to sensations which we do not perceive. If any apparatus could be devised by which the number of vibrations produced by any given cause could be lowered so as to be brought within the range of our ears, it is probable that the result would be most interesting.

VIII.

1. I have made a number of experiments on the power of smell possessed by ants. I dipped camel's-hair brushes into peppermint-water, essence of cloves, lavender-water, and other strong scents, and suspended them about a quarter of an inch above the strips of paper along which the ants were passing in the experiments above recorded. Under these circumstances, while some of the ants passed on without taking any notice, others stopped when they came close to the pencil, and, evidently perceiving the smell, turned back. Soon, however, they returned and passed the scented pencil. After doing this two or three times they generally took no further notice of the scent. This experiment left no doubt on my mind; still, to make the matter even more clear, I experimented with ants placed on an isolated strip of paper. Over the paper, and at such a distance as almost, but not quite, to touch any ant which passed under it, I again suspended a camel's-hair brush, dipped in assafœtida, lavender-water, peppermint-water, essence of cloves, and other scents. In these experiments the results were very marked; and no one who watched the behaviour of the ants under these circumstances

could have the slightest doubt as to their power of smell.

2. I then took a large queen ant and tethered her on a board by a thread. When she was quite quiet I tried her with the tuning-forks, but they did not disturb her in the least. I then approached the feather of a pen very quietly, so as almost to touch first one and then the other of the antennæ, which, however, did not move. I then dipped the pen in essence of musk, and did the same: the antenna was slowly retracted and drawn quite back. I then repeated the same with the other antenna. If I touched the antenna, the ant started away apparently smarting. I repeated the same with essence of lavender, and with a second ant. The result was the same.

Many of my other experiments point to the same conclusion; and, in fact, there can be no doubt whatever that in ants the sense of smell is highly developed.

3. In order to test the intelligence of ants, it has always seemed to me that there was no better way than to ascertain some object which they would clearly desire, and then to interpose some obstacle which a little ingenuity would enable them to overcome. I therefore placed some larvæ in a cup which I put on a slip of glass surrounded by water, but accessible to the ants by one pathway, in which was a bridge consisting of a strip of paper two-thirds of an inch long and one-third of an inch

wide. Having then put a **Black Ant** from one of my nests to these larvæ, she began carrying them off, and by degrees a number of friends came to help her. I then, when about 25 ants were so engaged, moved the little paper bridge slightly, so as to leave a chasm just so wide that the ants could not reach across. They came and tried hard to do so; but it did not occur to them to push the paper bridge, though the distance was only about one-third of an inch, and they might easily have done so. After trying for about a quarter of an hour they gave up the attempt, and returned home. This I repeated several times.

4. Then, thinking that paper was a substance to which they were not accustomed, I tried the same with a bit of straw one inch long and one-eighth of an inch wide. The result was the same. I repeated this more than once.

Again, I suspended some honey over a nest of **Yellow Ants** at a height of about half an inch, and accessible only by a paper bridge more than 10 feet long. Under the glass I then placed a small heap of earth. The ants soon swarmed over the earth on to the glass, and began feeding on the honey. I then removed a little of the earth, so that there was an interval of about one-third of an inch between the glass and the earth; but, though the distance was so small, they would not jump down, but preferred to go round by the long bridge. They tried in vain to stretch up from the earth to the glass,

which, however, was just out of their reach, though they could touch it with their antennæ; but it did not occur to them to heap the earth up a little, though if they had moved only half a dozen particles of earth they would have secured for themselves direct access to the food. At length they gave up all attempts to reach up to the glass, and went round by the paper bridge. I left the arrangement for several weeks, but they continued to go round by the long paper bridge.

5. Again I varied the experiment as follows:—Having left a nest without food for a short time, I placed some honey on a small wooden brick surrounded by a little moat of glycerine half an inch wide and about one-tenth of an inch in depth. Over this moat I then placed a paper bridge, one end of which rested on some fine mould. I then put an ant to the honey, and soon a little crowd was collected round it. I then removed the paper bridge: the ants could not cross the glycerine; they came to the edge and walked round and round, but were unable to get across, nor did it occur to them to make a bridge or bank across the glycerine with the mould which I had placed so conveniently for them. I was the more surprised at this on account of the ingenuity with which they avail themselves of earth for constructing their nests. For instance, wishing, if possible, to avoid the trouble of frequently moistening the earth in my nests, I supplied one of my communities with a

frame containing, instead of earth, a piece of linen, one portion of which projected beyond the frame and was immersed in water. The linen then sucked up the water by capillary attraction, and thus the air in the frame was kept moist. The ants approved of this arrangement, and took up their quarters in the frame. To minimize evaporation I usually closed the frames all round, leaving only one or two small openings for the ants, but in this case I left the outer side of the frame open. The ants, however, did not like being thus exposed; they, therefore, brought earth from some little distance, and built up a regular wall along the open side, blocking up the space between the upper and lower plates of glass, and leaving only one or two small openings for themselves. This struck me as very ingenious. The same expedient was, moreover, repeated under similar circumstances by the slaves belonging to my nest of **Amazon Ants.**

SECTION II.—BEES AND WASPS.

I.

1. Originally I had intended to make my experiments principally with bees, but soon found that ants were on the whole more suitable for my purpose.

In the first place, ants are much less excitable, they are less liable to accidents, and from the absence of wings are more easy to keep under continuous observation.

Still, I have made a certain number of observations with bees, some of which may be worth recording here.

As already mentioned, the current statements with reference to the language of social insects depend much on the fact that when one of them, either by accident or in the course of its rambles, has discovered a stock of food, in a very short time many others arrive to profit by the discovery. This, however, does not necessarily imply any power of describing localities. If the bees or ants merely follow their more fortunate comrade, the matter is comparatively simple; if, on the contrary, others are sent, the case becomes very different.

2. In order to test this I proposed to keep honey in a given place for some time, so as to satisfy myself that it would not readily be found by the bees; and then, after bringing a bee to the honey, to watch whether it brought others, or sent them—the latter, of course, implying a much higher order of intelligence and power of communication.

I never, however, could satisfy myself that bees which had found a store of honey sent others to it: the rest, if they came at all, were, as far as I could ascertain, always brought.

3. The result of my experiments on the **hearing of bees** has surprised me very much. It is generally considered that to a certain extent the emotions of bees are expressed by the sounds they make, which seems to imply that they possess the power of hearing. I do not by any means intend to deny that this is the case. Nevertheless, I never found them take any notice of any noise which I made, even when it was close to them. I tried one of my bees with a violin. I made all the noise I could, but to my surprise she took no notice. I could not even see a twitch of the antennæ. The next day I tried the same with another bee, but could not see the slightest sign that she was conscious of the noise. I have tried several bees with a dog-whistle and a shrill pipe; but they took no notice whatever, nor did a set of tuning-forks, which I tried on a subsequent day, have any more effect. These tuning-forks extended over three octaves,

beginning with *a* below the ledger line. I also tried with my voice, shouting, &c., close to the head of a bee; but, in spite of my utmost efforts, the bees took no notice. I repeated these experiments at night, when the bees were quiet; but no noise that I could make seemed to disturb them in the least.

4. The consideration of the causes which have led to the structure and colouring of flowers is one of the most fascinating parts of natural history. Most botanists are now agreed that insects, and especially bees, have played a very important part in the development of flowers. While in many plants, almost invariably with inconspicuous blossoms, the pollen is carried from flower to flower by the wind, in the case of almost all large and brightly coloured flowers this is effected by the agency of insects. In such flowers the colours, scent, and honey serve to attract insects, while the size and form are arranged in such a manner that the insects fertilise them with pollen brought from another plant.

5. There could, therefore, be little doubt that bees possess a **sense of colour.** Nevertheless, I thought it would be desirable to prove this, if possible, by actual experiment, which had not yet been done. Accordingly, on July 12, I brought a bee to some honey which I had placed on blue paper, and about 3 feet off I placed a similar quantity of honey on orange paper. After she had returned twice I transposed the papers; but she returned to the honey on

the blue paper. After she had made three more visits, always to the blue paper, I transposed them again, and she again followed the colour, though the honey was left in the same place. The following day I was not able to watch her; but on the 14th at—

7.29 A.M. she returned to the honey on the blue paper . . .	At 7.31 she left.
7.34 „ „	„ 7.41 „
7.56 „ „	

I then again transposed the papers. At 8.5 she returned to the old place, and was just going to alight; but observing the change of colours, without a moment's hesitation darted off to the blue. No one who saw her at that moment could have entertained the slighest doubt that she perceived the difference between the two colours.

6. On October 2 I placed some honey on slips of glass resting on black, white, yellow, orange, green, blue, and red paper. A bee which was placed on the orange returned twenty times to that slip of glass, only once or twice visiting the others, though I moved the position and also the honey. The next morning again two or three bees paid twenty-one visits to the orange and yellow, and only four to all the other slips of glass. I then moved the glass, after which, out of thirty-two visits, twenty-two were to the orange and yellow. This was due, I believe, to the bee having been placed on the

orange at the beginning of the experiment. I do not attribute it to any preference for the orange or yellow; indeed, I shall presently give reasons for considering that blue is the favourite colour of bees.

7. I had ranged my colours in a line, with the blue at one end. It was a cold morning, and only one bee came. She had been several times the preceding day, generally to the honey which was on the blue paper. This day also she came to the blue; I moved the blue gradually along the line one stage every half-hour, during which time she paid fifteen visits to the honey, in every case going to that which was on the blue paper.

These experiments only prove that bees have the power of distinguishing one colour from another. I afterwards, however, made a second series of experiments which indicated that they prefer blue to either red, white, yellow, or green.

II.

1. I have been much struck by the industry of wasps. They commence work early in the morning, and do not leave off till dusk. I have several times watched a wasp the whole day, and from morning to evening, if not disturbed, she worked without any interval for rest or refreshment.

Being anxious to compare bees and wasps in this respect, on August 6, 1882, I accustomed a wasp and three bees to come to some honey put out for them on two tables, one allotted to the wasp, the other to the bees. The last bee came at 7.15 P.M. The wasp continued working regularly till 7.47, coming at intervals of between six and seven minutes. Next morning, when I went into my study a few minutes after 4 A.M., I found the wasp already at the honey. The first bee came at 5.45, the second at 6.

It would, however, perhaps be unfair to the bees to regard this as indicating that they are less industrious than wasps. The deficiency may be due to their being more susceptible to cold.

2. The wasp occupied about a minute, or even less, in supplying herself with honey, and made during the day no less than 116 visits to the store, or 232 journeys between my room and her nest,

during which she carried off rather more than 64 grains of honey.

I may add that I then left home for a few days. I covered over the honey, leaving only a small entrance for the wasp. When I returned on the 12th, I found her still at work, and by herself. It was evident that she had continued her labours, but without bringing any friends to assist her.

My wasps, though courageous, were always on the alert, and easily startled. It was, for instance, more difficult to paint them than the bees; nevertheless, though I tried them with a set of tuning-forks covering three octaves, with a shrill whistle, a pipe, a violin, and my own voice, making in each case the loudest and shrillest sounds in my power, I could see no symptoms in any case that they were conscious of the noise.

3. The following fact struck me as rather remarkable. One of my wasps smeared her wings with syrup, so that she could not fly. When this happened to a bee, it was only necessary to carry her to the alighting-board of the hive, when she was soon cleaned by her comrades. But I did not know where this wasp's nest was, and therefore could not pursue a similar course with her. At first, then, I was afraid that she was doomed. I thought, however, that I would wash her, fully expecting, indeed, to terrify her so much that she would not return again. I caught her, put her in a bottle half full of water, and shook her up well till the honey was

washed off. I then transferred her to another bottle, and put her in the sun to dry. When she appeared to have recovered I let her out: she at once flew to her nest, and I never expected to see her again. To my surprise, in 13 minutes she returned as if nothing had happened, and continued her visits to the honey all the afternoon.

4. This experiment interested me so much that I repeated it with another marked wasp, this time, however, keeping the wasp in the water till she was quite motionless and insensible. When taken out of the water she soon recovered; I fed her; she went quietly away to her nest as usual, and returned after the usual absence. The next morning this wasp was the first to visit the honey.

I once kept a **tame wasp** for no less than nine months.

I took her, with her nest, in the Pyrenees, early in May. The nest consisted of about 20 cells, the majority of which each contained an egg; but as yet no grubs had been hatched out, and, of course, my wasp was still alone in the world.

5. I had no difficulty in inducing her to feed on my hand; but at first she was shy and nervous. She kept her sting in constant readiness; and once or twice in the train, when the railway officials came for tickets, and I was compelled to hurry her back into her bottle, she stung me slightly—I think, however, entirely from fright.

Gradually she became quite used to me, and

when I took her on my hand apparently expected to be fed. She even allowed me to stroke her without any appearance of fear, and for some months I never saw her sting.

When the cold weather came on she fell into a drowsy state, and I began to hope she would hibernate and survive the winter. I kept her in a dark place, but watched her carefully, and fed her if ever she seemed at all restless.

6. She came out occasionally, and seemed as well as usual till near the end of February, when one day I observed she had nearly lost the use of her antennæ, though the rest of the body was as usual. She would take no food. Next day I tried again to feed her; but the head seemed dead, though she could still move her legs, wings, and abdomen. The following day I offered her food for the last time; but both head and thorax were dead or paralysed; she could but move her tail, a last token, as I could almost fancy, of gratitude and affection. As far as I could judge, her death was quite painless; and she now occupies a place in the British Museum.

As regards **colours**, I satisfied myself that **wasps** are capable of distinguishing colour, though they do not seem so much guided by it as bees are.

7. One day, at 7 A.M., I marked a **common worker wasp** (*Vespa vulgaris*), and placed her to some honey on a piece of green paper 7 inches by 4½. She worked with great industry. After she

had got well used to the green paper I moved it 18 inches off, putting some other honey on blue paper where the green had previously been. She returned to the blue. I then replaced the green paper for an hour, during which she visited it several times, after which I moved it 18 inches, as before, and put brick-red paper in its place. She returned to the brick-red paper. But although this experiment indicates that this wasp was less strongly affected by colours than the bees which I had previously observed, still I satisfied myself that she was not colour-blind.

8. I moved the green paper slightly and put the honey, which, as before, was on a slip of plain glass, about 4 feet off. She came back and lit on the green paper, but finding no honey, rose again, and hawked about in search of it. After 90 seconds I put the green paper under the honey, and in 15 seconds she found it. Then, while she was absent at the nest, I moved both the honey and the paper about a foot from their previous positions, and placed them about a foot apart. She returned as usual, hovered over the paper, lit on it, rose again, flew about for a few seconds, lit again on the paper, and again rose. After two minutes had elapsed I slipped the paper under the honey, when she almost immediately (within five seconds) lit on it. It seems obvious, therefore, that she could see green.

9. I then tried her with red. I placed the honey on brick-red paper, and left her for an hour, from

5 P.M. to 6 P.M., to get accustomed to it. During this time she continued her usual visits. I then put the honey and the coloured paper about a foot apart; she returned first to the paper and then to the honey. I then transposed the honey and the paper. This seemed to puzzle her. She returned to the paper, but did not settle. After she had hawked about for 100 seconds I put the honey on the red paper, when she settled on it at once. I then put the paper and the honey again 18 inches apart. As before, she returned first to the paper, but almost immediately went to the honey. In a similar manner I satisfied myself that she could see yellow.

10. Again, on August 18 I experimented on two wasps, one of which had been coming more or less regularly to some honey on yellow paper for four days, the other for twelve—coming, that is to say, for several days the whole day long, and on all the others, with two or three exceptions, for at least three hours in the day. Both, therefore, had got well used to the yellow paper. I then put blue paper where the yellow had been, and put the yellow paper with some honey on it about a foot off. Both the wasps returned to the honey on the blue paper. I then moved both the papers about a foot, but so that the blue was somewhat nearer the original position. Both again returned to the blue. I then transposed the colours, and they both returned to the yellow.

SECTION III.—THE COLOURS OF ANIMALS.

I.

1. There are few more interesting parts of natural history than the study of the causes which have led to the present **colours of animals and plants.** As regards plants, and especially flowers, I shall have something to say in a future chapter, and I will now therefore confine myself to animals.

The colour of animals is by no means a matter of chance; it depends on many considerations, but in the majority of cases tends to protect the animal from danger by rendering it less conspicuous.

Perhaps it may be said that if colouring is mainly protective, there ought to be but few brightly-coloured animals. There are, however, not a few cases in which vivid colours are themselves protective. The kingfisher itself, though so brightly coloured, is by no means easy to see. The blue harmonises with the water, and as it darts along the stream it looks almost like a flash of sunlight; besides which, protection is not the only considera-

tion. Let us now consider the prevalent colours of animals and see how far they support the rule.

2. Desert animals, for instance, are generally the colour of the desert. Thus, for instance, the **lion,** the **antelope**, and the **wild ass** are all sand-coloured. "Indeed," says Canon Tristram, "in the desert, where neither trees, brushwood, nor even undulation of the surface afford the slightest protection to its foes, a modification of colour which shall be assimilated to that of the surrounding country, is absolutely necessary. Hence, without exception, the upper plumage of every bird, whether lark, chat, sylvain, or sand grouse, and also the fur of all the smaller mammals and the skin of all the snakes and lizards, is of one uniform sand colour."

It is interesting to note that, while the lion is sand-coloured like the desert, the long, upright yellow stripes of the tiger make it very difficult to see the animal among the long dry grasses of the Indian jungles in which it lives. The leopard, again, and other tree cats are generally marked with spots which resemble gleams of light glancing through the leaves.

3. The colours of birds are in many cases perhaps connected with the position and mode of construction of their nests. Thus, we know that hen birds are generally less brightly coloured than the cocks, and this is partly, perhaps, because bright colours would be a danger to the hens while sitting on their eggs. When the nest is placed underground or in

the hole of a tree, &c., we find it no longer to be such an invariable rule that the hen bird is dull-coloured; but, on the contrary, she is then often as gaily-coloured as the male. Such, for instance, is the case with the hen kingfisher, which is one of the brightest of British birds and one of the very few which make their nests underground ; the hen woodpecker, which is also gaily-coloured and builds in hollow trees, forms a second instance.

In the few cases where the hens are as conspicuously coloured as the cocks, and yet the nest is open to view, we generally find that the hens are strong, pugnacious birds, and well able to defend themselves. There are even instances, though these are comparatively rare, in which the hens are more brilliantly-coloured than the cocks ; and it is an interesting fact that it is then the cocks, and not the hens, which hatch the eggs.

4. It therefore seems to be a rule, with very few exceptions, that when both the cocks and hens are of strikingly gay or conspicuous colours, the nest is such as to conceal the sitting bird ; while, whenever there is a striking contrast of colours, the nest is open and the sitting bird exposed to view.

Again, most **fishes** are dark above and pale below. This points to the same fact, for when one looks down into the dark water, the dark colour of their backs renders them the less easy to distinguish ; while, to an enemy looking up from below, the pale belly would be less conspicuous against

the light of the sky. Those fishes which live deep down in the depths of the ocean present no such contrast between the upper and under surface. Many of the smaller animals which live in the sea are as transparent as glass, and are consequently very difficult to distinguish.

5. It is sometimes said that if animals were really coloured with reference to concealment, **sheep** would be green, like grass. This, however, is quite a mistake. If they were green they would really be more easy to see. In the grey of the morning and the evening twilight, just the time when wild animals generally feed, grey and stone colours are most difficult to distinguish. Sheep were originally mountain animals, and everyone who has ever been on a mountain-side knows how difficult it is to distinguish a sheep, at some distance, from a mass of stone or rock.

6. It is, again, a great advantage to the **rabbit** and **hare** to be coloured like earth; black or white rabbits are more easy to see, and consequently more likely to be killed. This, however, does not apply to those which are kept in captivity, and we know that tame rabbits are often black and white. Again, in the far north, where for months together the ground is covered with snow, the white colour, which would be a danger here, becomes an advantage; and many arctic animals, like the **polar bear** and **polar hare**, are white, while others, such as the **mountain hare** and **ptarmigan**, change their

colour, being brown in summer and white in winter. So are the **arctic fox** and the **ermine**, to whom it is then an advantage to be white, not to avoid danger, but in order that they may be the more easily able to steal unperceived upon their prey.

7. Many of the cases in which certain insects escape danger by their similarity to plants are well known; the **leaf insect** and the **walking-stick insect*** are familiar and most remarkable cases. The larvæ of insects afford, also, many interesting examples, and in other respects teach us, indeed, many instructive lessons. It would be a great mistake to regard them as merely preparatory stages in the development of the perfect insect. They are much more than this, for external circumstances act on the larvæ, as well as on the perfect insect: both, therefore, are liable to adaptation. In fact, the modifications which insect larvæ undergo may be divided into two kinds—developmental, or those which tend to approximation to the mature form; and adaptational or adaptive, those which tend to suit them to their own mode of life.

8. It is a remarkable fact, that the forms of larvæ do not depend on those of the mature insect. In many cases, for instance, very similar larvæ produce extremely dissimilar insects. In other cases, similar, or comparatively similar, perfect insects have very

* These are insects which inhabit warm regions, and they are so called because they so strikingly resemble leaves, and bits of stick, respectively.

dissimilar larvæ. Indeed, a classification of insects founded on larvæ would be quite different from that founded on the perfect insects. The group to which the bees, wasps, and ants belong, for instance, and which, so far as the perfect insects are concerned, form a very natural division, would be divided into two; or rather one portion of them—namely, the saw-flies—would be united to the butterflies and moths. Now, why do the larvæ of saw-flies differ from those of their allies, and resemble those of butterflies and moths? It is because their habits differ from those of ants and bees, and they feed on leaves like ordinary caterpillars.

9. In some cases the form changes considerably during the larval state. From this point of view, the transformations of a small beetle, called *Sitaris*, which have been carefully observed by M. Fabre, are peculiarly interesting.

10. The genus *Sitaris*, which is allied to the **blister-fly** and to the **oil-beetle,** is parasitic on a kind of solitary bee which excavates subterranean galleries, each leading to a cell. The eggs of the beetle, which are deposited at the entrance of the galleries made by the bees, are hatched at the end of September or beginning of October, and we might not unnaturally expect that the young larvæ, which are active little creatures with six serviceable legs, would at once eat their way into the cells of the bee. No such thing: till the month of April

following they remain without leaving their birth-place, and consequently without food; nor do they in this long time change either in form or size. M. Fabre ascertained this, not only by examining the burrow of the bees, but also by direct observations of some young larvæ kept in captivity. In April, however, his captives at last awoke from their long lethargy, and hurried anxiously about their prisons. Naturally inferring that they were in search of food, M. Fabre supposed that this would consist either of the larvæ or pupæ of the bee, or of the honey with which it stores its cell. All three were tried without success. The first two were neglected; and the larvæ, when placed on the latter, either hurried away or perished in the attempt, being evidently unable to deal with the sticky substance. M. Fabre was in despair. The first ray of light came to him from our countryman Newport, who ascertained that a small parasite found on one of the wild bees was, in fact, the larva of the oil-beetle. The larvæ of *Sitaris* much resembled this larva. Acting on this hint, M. Fabre examined many specimens of the bee, and found on them at last the larvæ of his *Sitaris*. The males of the bee emerge from the pupæ sooner than the females, and M. Fabre ascertained that, as they come out of their galleries, the little *Sitaris* larvæ fasten upon them. Not, however, for long: instinct teaches them that they are not yet in the straight path of development; and, watching their

opportunity, they pass from the male to the female bee. Guided by these indications, M. Fabre examined several cells of the bee ; in some, the egg of the bee floated by itself on the surface of the honey ; in others, on the egg, as on a raft, sat the still more minute larva of the *Sitaris*. The mystery was solved. At the moment when the egg is laid, the *Sitaris* larva springs upon it. Even while the poor mother is carefully fastening up her cell, her mortal enemy is beginning to devour her offspring ; for the egg of the bee serves not only as a raft, but as a repast. The honey, which is enough for either, would be too little for both ; and the *Sitaris*, therefore, at its first meal, relieves itself from its only rival. After eight days the egg is consumed, and on the empty shell the *Sitaris* undergoes its first transformation, and makes its appearance in a very different form.

11. The honey, which was fatal before, is now necessary—the activity, which before was necessary, is now useless ; consequently, with the change of skin, the active, slim larva changes into a white fleshy grub, so organised as to float on the surface of the honey, with the mouth beneath and the breathing-holes above the surface ; for insects breathe, not as we do through the mouth, but through a row of holes arranged along the side. In this state it remains until the honey is consumed ; then the animal contracts, and detaches itself from its skin, within which the further transformations take place.

In the next stage the larva has a solid corneous envelope and an oval shape, and, in its colour, consistency, and immobility, resembles the chrysalis of a fly. The time passed in this condition varies much. When it has elapsed, the animal moults again, again changes its form ; after this, it becomes a pupa, without any remarkable peculiarities. Finally, after these wonderful changes and adventures, in the month of August the perfect beetle makes its appearance.

II.

1. In fact, whenever in any group we find differences in form or colour, we shall always find them associated with differences in habit. Let us take the case of **Caterpillars.** The prevailing colour of caterpillars is green, like that of leaves. The value of this to the young insect, the protection it affords, are obvious. We must all have observed how difficult it is to distinguish small green caterpillars from the leaves on which they feed. When, however, they become somewhat larger, their form betrays them, and it is important that there should be certain marks to divert the eye from the outlines of the body. This is effected, and much protection is given, by longitudinal lines (fig. 11), which accordingly are found on a great many caterpillars. These lines, both in colour and thickness, much resemble some of the lines on leaves (especially those, for instance, of grasses), and also the streaks of shadow which occur among foliage. If, however, this be the explanation of them, then they ought to be wanting, as a general rule, in very small caterpillars, and should prevail most among those which feed on or among grasses.

2. Now, similar lines occur on a great number of caterpillars belonging to most different groups of

butterflies and moths, as you may see by turning over the illustrations of any monograph of the group. They exist among the **Hawk-moths**—as, for instance, in the Humming-bird Hawk-moth; they

Fig. 11.—The Caterpillar of the MARBLED WHITE BUTTERFLY (*Arge galathea*).

occur in many butterflies, especially in those which feed on grass; and in many moths. But you will find that the smallest caterpillars rarely possess these white streaks. As regards the second point,

also, the streaks are generally wanting in caterpillars which feed on large-leaved plants. The *Satyridæ*, on the contrary, all possess them, and all live on grass. In fact we may say, as a general rule, that these longitudinal streaks only occur on caterpillars which live on or among narrow-leaved plants. As the insect grows, these lines often disappear on certain segments, and are replaced by diagonal lines. These diagonal lines (fig. 12) occur in a great many caterpillars, belonging to the most distinct families of butterflies and moths. They come off just at the same angle as the ribs of leaves, and resemble them very much in general effect. They occur also especially on species which feed on large-leaved plants; and I believe I may say that though a great many species of caterpillars present these lines, they rarely, if ever, occur in species which live on grass; while, on the contrary, they are very frequent in those species which live on large-leaved plants.

3. It might at first be objected to this view that there are many cases, as in the **Elephant Hawk-moth**, in which caterpillars have both. A little consideration, however, will explain this. In small caterpillars these oblique lines would be useless, because they must have some relation, not only in colour, but in their distance apart, to the ribs of the leaves. Hence, while there are a great many species which have longitudinal lines when young, and diagonal ones when they are older

and larger, there is not, I believe, a single one which begins with diagonal lines, and then replaces them with longitudinal ones. The disappearance of the longitudinal lines on those segments which

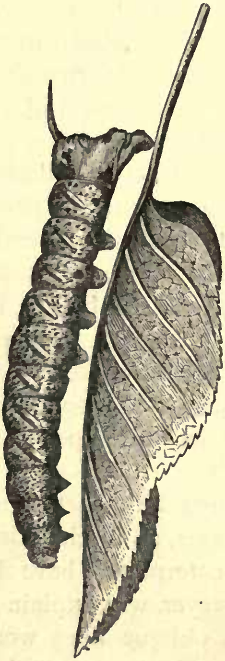


Fig. 12.—The Caterpillar of the Eyed Hawk-moth (*Smerinthus ocellatus*).

have diagonal ones, is striking, where the lines are marked. It is an advantage, because white lines crossing one another at such an angle have no relation to anything which occurs in plants,

and would make the creature more conspicuous When, therefore, the diagonal lines are developed, the longitudinal ones often disappear. There is one other point in connection with these diagonal lines to which I must call your attention.

4. In many species they are white, but in some cases—as, for instance, in the beautiful green caterpillar of the **Privet Hawk-moth**—the white streak is accompanied by a coloured one, in that case lilac. At first we might think that this would be a disadvantage, as tending to make the caterpillar more conspicuous; and in fact, if we put one in full view—for instance, out on a table—and focus the eye on it, the coloured lines are very striking. But we must remember that the habit of the insect is to sit on the lower side of the leaf, generally near the middle rib, and in the subdued light of such a situation, especially if the eye be not looking exactly at them, the coloured lines beautifully simulate a line of soft shadow, such as must always accompany a strong rib; and I need not tell any artist that the shadows of yellowish-green must be purplish. Moreover, any one who has ever found one of these large caterpillars will, I am sure, agree with me that it is surprising, when we consider their size and conspicuous colouring, how difficult it is to see them.

5. But though the prevailing colour of caterpillars is green, there are numerous exceptions. In one great family of moths the prevailing colour is brown.

These caterpillars, however, escape observation by their great similarity to brown twigs—a resemblance which is heightened by their peculiar attitudes, and in many cases by the existence of warts or protuberances, which look like buds. Some, however, even of these caterpillars, when very young, are green. Again, some caterpillars are white. These feed on and burrow in wood. The **Ringlet Butterfly** also has whitish caterpillars, and this may at first sight appear to contradict the rule, since it feeds on grass. Its habit is, however, to keep at the roots by day, and feed only at night.

6. In various genera we find **Black caterpillars**, which are of course very conspicuous, and, so far as I know, not distasteful to birds. In such cases, however, it will be found that they are covered with hairs or spines, which protect them from most birds. In these species the bold dark colour may be an advantage, by rendering the hair more conspicuous. Many caterpillars are black and hairy, but I do not know any large caterpillar which is black and smooth.

7. **Brown caterpillars**, also, are frequently protected by hairs or spines in the same way; but, unlike black ones, they are frequently naked. These fall into two principal categories: firstly, those which, like the *Geometridæ*, put themselves into peculiar and stiff attitudes, so that in form, colour, and position they closely resemble bits of dry stick; and, secondly, those which feed on low plants, con-

cealing themselves on the ground by day, and only coming out in the dark.

Yellow and yellowish-green caterpillars are abundant, and their colour is a protection. Red and blue, on the contrary, are much less common colours, and are generally present as spots.

8. Moreover, caterpillars with red lines or spots are generally hairy, and this for the reason given above. Such species, therefore, would be avoided by birds. There are, no doubt, some apparent exceptions. The **Swallow-tail Butterfly**, for instance, has red spots and still is smooth; but as it emits a strongly-scented liquid when alarmed, it is probably distasteful to birds. I cannot recall any other case of a British caterpillar which has conspicuous red spots or lines, and yet is smooth.

9. Blue is, among caterpillars, even a rarer colour than red. Indeed, among our larger larvæ, the only cases I can recall are the **Lappets**, which have two conspicuous blue bands, the **Death's-head Moth**, which has broad diagonal bands, and two of the **Hawk-moths**, which have two bright blue oval patches on the third segment. The Lappets are protected by being hairy, but why they have the blue bands I have no idea. It is interesting, that both the other species frequent plants which have blue flowers. The peculiar hues of the Death's-head caterpillar, which feeds on the potato, unite so beautifully the brown of the earth, the yellow and green of the leaves, and the blue

of the flowers, that, in spite of its size, it can scarcely be perceived unless the eye be focussed exactly upon it.

10. The **Oleander Hawk-moth** is also an interesting case. Many of the Hawk-moth caterpillars have eye-like spots, to which I shall have to allude again presently. These are generally reddish or yellowish, but in this species, which feeds on the periwinkle, they are bright blue, and in form as well as colour closely resemble the blue petals of that flower. One other species, the **Sharp-winged Hawk-moth**, also has two smaller blue spots, with reference to which I can make no suggestion. It is a very rare species, and I have never seen it. Possibly, in this case, the blue spots may be an inherited character, and have no reference to the present habits. They are, at any rate, quite small.

11. No one who looks at any representations of Hawk-moth caterpillars can fail to be struck by the peculiar colouring of those belonging to the **Pine Moth**, which differ in style of colouring from all other sphinx larvæ, having longitudinal bands of brown and green. Why is this? Their *habitat* is different. They feed on the leaves of the pinaster, and their peculiar colouring offers a general similarity to the brown twigs and narrow green leaves of a conifer. There are not many species of butterflies or moths which feed on the pine, but there are a few: and most, if not all of them, have a very analogous style of colouring

to that of the Pine Moth, while the latter has also tufts of bluish-green hair which singularly mimic the leaves of the pine. It is still more remarkable that in a different order of insects we again find species—for instance one of the saw-flies—which live on the pine, and in which the same style of colouring is repeated.

III.

1. Let us now take a single group, and see how far we can explain its various colours and markings, and what are the lessons which they teach us. For this purpose, I think I cannot do better than select the larvæ of the hawk-moths, which have just been the subject of a masterly work by Dr. Weissmann, from which most of the following facts are taken.

The caterpillars of this group are very different in colour—green, white, yellow, brown, sometimes even gaudy, varied with spots, patches, streaks, and lines. Now, are these differences merely casual and accidental, or have they a meaning and a purpose? In many, perhaps in most cases, the markings serve for the purpose of concealment. When, indeed, we see caterpillars represented on a white sheet of paper, or if we put them on a plain table, and focus the eye on them, the colours and markings would seem, if possible, to render them even more conspicuous; but amongst the intricate lines and varied colours of foliage and flowers, and if the insect be a little out of focus, the effect is very different.

2. Let us begin with the **Elephant Hawk-moth.** The caterpillars (fig. 13), as represented in most entomological works, are of two varieties, most of

them brown, but some green. Both have a white line on the three first segments; two remarkable eye-like spots on the fourth and fifth, and a very

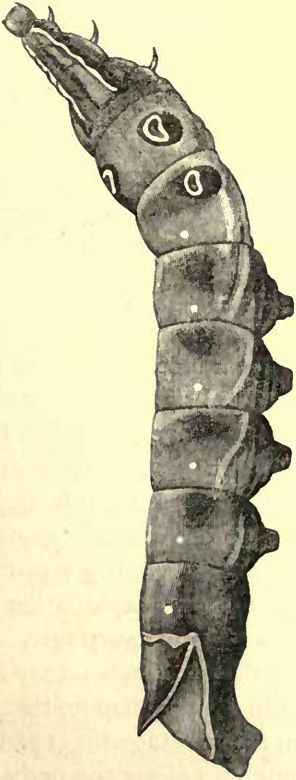


Fig. 13.—The Caterpillar of the Elephant Hawk-moth (*Chærocampa elpenor*). Full grown. Natural size.

faint median line; and are rather more than four inches long. I will direct your attention specially, for the moment, to three points:—What do the

eye-spots and the faint lateral line mean? and why are some green and some brown, offering thus such a marked contrast to the leaves of the small epilobe on which they feed? Other questions will suggest themselves later. I must now call your attention to the fact that, when the caterpillars first quit the egg, and come into the world (fig. 14), they are

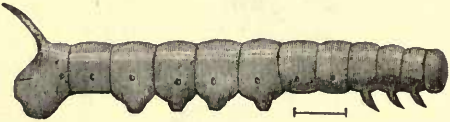


Fig. 14.—The Caterpillar of the ELEPHANT HAWK-MOTH (*Chærocampa elpenor*). First Stage.

quite different in appearance, being, like so many other small caterpillars, bright green, and almost exactly the colour of the leaves on which they feed. That this colour is not the necessary or direct consequence of the food, we see from the case of quadrupeds, which, as I need scarcely say, are never green. It is, however, so obviously a protection to small caterpillars, that this explanation of their green colour suggests itself to every one.

3. After five or six days, and when they are about a quarter of an inch in length, they go through their first moult. In their second stage (fig. 15), they have two white lines, stretching along the body from the horn to the head; and after a few days (fig. 16), but not at first, traces of the eye-spots appear on the fourth and fifth segments, shown by a slight

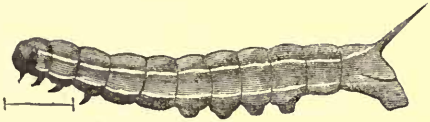


Fig. 15.—The Caterpillar of the ELEPHANT HAWK-MOTH (*Chærocampa elpenor*). Second Stage.

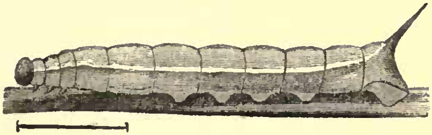


Fig. 16.—The Caterpillar of the ELEPHANT HAWK-MOTH (*Chærocampa elpenor*). Just before the second moult.

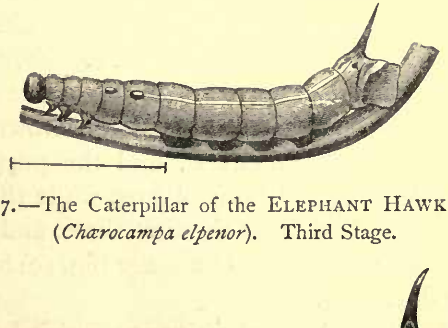


Fig. 17.—The Caterpillar of the ELEPHANT HAWK-MOTH (*Chærocampa elpenor*). Third Stage.

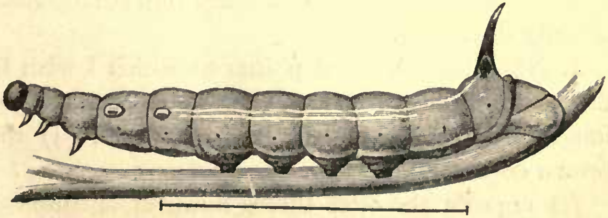


Fig. 18.—The Caterpillar of the ELEPHANT HAWK-MOTH (*Chærocampa elpenor*). Fourth Stage.

wave in the upper line. After another five or six days, and when about half an inch in length, our caterpillars moult again. In their third stage (fig. 17), the commencement of the eye-spots is more marked, while, on the contrary, the lower longitudinal line has disappeared. After another moult (fig. 18), the eye-spots are still more distinct, the white gradually becomes surrounded by a black line, while in the next stage (fig. 19) the centre becomes somewhat violet. The white lines have almost or entirely disappeared, and in some specimens faint diagonal lines make their appearance. Some few assume a brownish tint, but not many. A fourth moult takes place in seven or eight days, and when the caterpillars are about an inch and a half in length. Now, the difference shows itself still more between the two varieties, some remaining green, while the majority become brown. The eye-spots are more marked, and the pupil more distinct, the diagonal lines plainer, while the white line is only indicated on the first three, and on the eleventh segment. The last stage (fig. 19) has been already described.

4. Now, the principal points to which I wish to draw attention are (1) the green colour, (2) the longitudinal lines, (3) the diagonal lines, (4) the brown colour, and (5) the eye-spots.

As regards the first three, however, I think I need say no more. The value of the green colour to the young larva is obvious; nor is it much less

clear that when the insect is somewhat larger, the longitudinal lines are a great advantage, while subsequently diagonal ones become even more important.

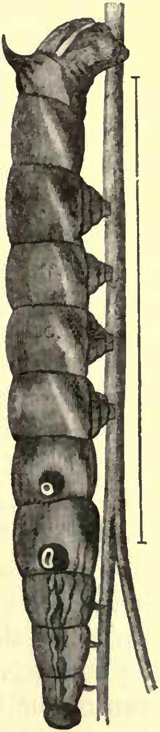


Fig. 19.—The Caterpillar of the ELEPHANT HAWK-MOTH (*Chærocampa elpenor*). Fifth Stage.

5. The next point is the colour of the mature caterpillars. We have seen that some are green, and others brown. The green ones are obviously merely those which have retained their original colour.

Now for the brown colour. This probably makes the caterpillar even more conspicuous among the green leaves than would otherwise be the case. Let us see, then, whether the habits of the insect will throw any light upon the riddle. What would you do if you were a big caterpillar? Why, like most other defenceless creatures, you would feed by night, and lie concealed by day. So do these caterpillars. When the morning light comes, they creep down the stem of the food plant, and lie concealed among the thick herbage, and dry sticks and leaves, near the ground; and it is obvious that under such circumstances the brown colour really becomes a protection. It might indeed be argued that the caterpillars, having become brown, concealed themselves on the ground; and that we were, in fact, reversing the state of things. But this is not so; because, while we may say, as a general rule, that (with some exceptions due to obvious causes) large caterpillars feed by night and lie concealed by day, it is by no means always the case that they are brown; some of them still retaining the green colour. We may then conclude that the habit of concealing themselves by day came first, and that the brown colour is a later adaptation. It is, moreover, interesting to note that while the caterpillars which live on low plants often go down to the ground and turn brown, those which feed on large trees or plants remain on the under side of the leaves, and retain their green colour.

6. Thus, in the **Eyed Hawk-moth**, which feeds on the willow and sallow; the **Poplar Hawk-moth** which feeds on the poplar; and the **Lime Hawk-moth**, which frequents the lime, the caterpillars all remain green; while in those which frequent low plants, such as the **Convolvulus Hawk-moth**, which frequents the convolvulus; the **Oleander Hawk-moth**, which feeds in this country on the periwinkle; and other species, most of the caterpillars turn brown. There are, indeed, some caterpillars which are brown, and still do not go down to the ground —as, for instance, those of the *Geometridæ* generally. These caterpillars, however, as already mentioned, place themselves in peculiar attitudes, which, combined with their brown colour, make them look almost exactly like bits of stick or dead twigs.

7. The last of the five points to which I called your attention was the eye-spots. In some cases, spots may serve for concealment, by resembling the marks on dead leaves. In one species, which feeds on the hippophae, or sea buckthorn, a grey-green plant, the caterpillar also is a similar grey-green, and has, when full grown, a single red spot on each side—which, as Weissmann suggests, at first sight much resembles in colour and size one of the berries of the hippophae. This might, at first, be supposed to constitute a danger, and therefore to be a disadvantage; but the seeds, though present, are not ripe, and consequently are not touched by

birds. Again, in another caterpillar, there is an eye-spot on each segment, which mimics the flower of the plant on which it feeds. White spots, in some cases, also resemble the spots of light which penetrate foliage. In other instances, however, and at any rate in our Elephant Hawk-moth, the eye-spots certainly render the insect more conspicuous.

8. Now in some cases, this is an advantage, rather than a drawback. Suppose that from the nature of its food, from its being covered with hair, or from any other cause, a small green caterpillar were very bitter, or disagreeable or dangerous as food, still, in the number of small green caterpillars which birds love, it would be continually swallowed by mistake. If, on the other hand, it had a conspicuous and peculiar colour, its evil taste would serve to protect it, because the birds would soon recognise and avoid it, as has been proved experimentally. I have already alluded to a case of this among the Hawk-moths, in a species which, feeding on euphorbia, with its bitter milky juice, is very distasteful to birds, and is thus actually protected by its bold and striking colours. The spots on our Elephant Hawk-moth caterpillar do not admit of this explanation, because the insect is quite good to eat—I mean, for birds. We must, therefore, if possible, account for these spots in some other way. There can, I think, be little doubt that Weissmann is right when he suggests that the eye-spots actually protect the caterpillar, by frightening its foes.

9. Every one must have observed that these large caterpillars—as, for instance, that of the small Elephant Hawk-moth (fig. 20)—have a sort of uncanny poisonous appearance; that they suggest

Fig. 20.—The Caterpillar of the Small Elephant Hawk-moth (*Chærocampa porcellus*).

a small thick snake or other evil beast, and the so-called "eyes" do much to increase the deception. Moreover, the segment on which they are placed is

swollen, and the insect, when in danger, has the habit of retracting its head and front segments, which gives it an additional resemblance to some small reptile. That small birds are, as a matter of fact, afraid of these caterpillars (which, however, I need not say, are in reality altogether harmless), Weissmann has proved by actual experiment. He put one of these caterpillars in a tray, in which he was accustomed to place seed for birds. Soon a little flock of sparrows and other small birds assembled to feed as usual. One of them lit on the edge of this tray, and was just going to hop in, when she spied the caterpillar. Immediately she began bobbing her head up and down, but was afraid to go nearer. Another joined her, and then another, until at last there was a little company of 10 or 12 birds, all looking on in astonishment, but not one ventured into the tray; while one bird, which lit in it unsuspectingly, beat a hasty retreat in evident alarm, as soon as she perceived the caterpillar. After watching for some time, Weissmann removed it, when the birds soon attacked the seeds. Other caterpillars also are probably protected by their curious resemblance to spotted snakes.

10. Moreover, we may learn another very interesting lesson from these caterpillars. They leave the egg, as we have seen, a plain green, like so many other caterpillars, and gradually acquire a succession of markings, the utility of which I have just attempted

to explain. The young larva, in fact, represents an old form, and the species, in the lapse of ages, has gone through the stage which each individual now passes through in a few weeks. Thus, the caterpillar of *Chœrocampa porcellus*, a species very nearly allied to the Elephant Hawk-moth, passes through almost exactly the same stages as that species. But it leaves the egg with a subdorsal line, which the caterpillar of the Elephant Hawk-moth does not acquire until after its first moult. No one can doubt, however, that there was a time when the new-born caterpillars of the small Elephant Hawk-moth were plain green, like those of the large one. Again, if we compare the mature caterpillars of this group of hawk-moths, we shall find there are some forms which never develop eye-spots, but which, even when full grown, correspond to the second stage of the Elephant Hawk-moth. Here, then, we seem to have species still in the stage which the Elephant Hawk-moth must have passed through long ago.

IV.

1. The genus *Deilephila*, of which we have in England three species—the **Euphorbia Hawk-moth**, the **Galium Hawk-moth**, and the **Rayed Hawk-moth**—is also very instructive. The caterpillar of the Euphorbia Hawk-moth begins life of a clear green colour, without a trace of the subsequent markings. After the first moult, however, it has a number of black patches, a white line, and a series of white dots, and has, therefore, at one bound, acquired characters which in the Elephant Hawk-moth, as we have seen, were only very gradually assumed. In the third stage, the line has disappeared, leaving the white spots. In the fourth, the caterpillars have become very variable, but are generally much darker than before, and have a number of white dots under the spots. In the fifth stage, there is a second row of white spots under the first. The caterpillars not being good to eat, there is, as has been already pointed out, no need for, or attempt at, concealment. Now if we compare the mature caterpillars of other species of the genus, we shall find that they represent phases in the development of the Euphorbia Hawk-moth. The **Sea Buckthorn Hawk-moth**, for instance, even when full grown, is a plain green, with only a trace of the line, and corresponds, there-

fore, with a very early stage of the Euphorbia Hawk-moth; there is another species found in South Russia, which has the line, and represents the second stage of the Euphorbia Hawk-moth; another has the line and the row of spots, and represents, therefore, the third stage; lastly, there are some which have progressed further, and lost the longitudinal line, but they never acquire the second row of spots which characterises the last stage of the Euphorbia Hawk-moth.

2. Thus, then, the individual life of certain caterpillars gives us a clue to the history of the species in past ages.

For such inquiries as this, the larvæ of **Lepidoptera** are particularly suitable, because they live an exposed life; because the different species, even of the same genus, often feed on different plants, and are therefore exposed to different conditions; and last, not least, because we know more about the larvæ of the butterflies and moths than about those of any other insects. The larvæ of ants all live in the dark; they are fed by the perfect ants, and being therefore all subject to very similar conditions, are all very much alike. It would puzzle even a good naturalist to determine the species of an ant larva, while, as we all know, the caterpillars of butterflies and moths are as easy to distinguish as the perfect insects; they differ from one another as much as, sometimes more than, the butterflies and moths themselves.

3. There are five principal types of colouring among caterpillars. Those which live inside wood, or leaves, or underground, are generally of an uniform pale hue; the small leaf-eating caterpillars are green, like the leaves on which they feed. The other three types may, to compare small things with great, be likened to the three types of colouring among cats. There are the ground cats, such as the lion or puma, which are brownish or sand colour, like the open places they frequent. So also caterpillars which conceal themselves by day at the roots of their food-plant, tend, as we have seen, even if originally green, to assume the colour of earth. Nor must I omit to mention the *Geometridæ*, to which I have already referred, and which, from their brown colour, their peculiar attitudes, and the frequent presence of warts or protuberances, closely mimic bits of dry stick. That the caterpillars of these species were originally green, we may infer from the fact that some of them at least are still of that colour when first born.

4. Then there are the spotted or eyed cats, such as the leopard, which live among trees; and their peculiar colouring renders them less conspicuous by simulating spots of light which penetrate through foliage. So also many caterpillars are marked with spots, eyes, or patches of colour. Lastly, there are the jungle cats, of which the tiger is the typical species, and which have stripes, rendering them very difficult to see among the brown grass which

they frequent. It may, perhaps, be said that this comparison fails, because the stripes of tigers are perpendicular, while those of caterpillars are either longitudinal or oblique. This, however, so far from constituting a real difference, confirms the explanation; because in each case the direction of the lines follows that of the foliage. The tiger, walking horizontally on the ground, has transverse bars; the caterpillar, clinging to the grass in a vertical position, has longitudinal lines; while those which live on large-veined leaves have oblique lines, like the oblique ribs of the leaves.

5. It might, however, be suggested that the cases given above are exceptional. I have, therefore, in another work, tabulated all our larger British caterpillars, and the result is very interesting. As regards butterflies, we have 66 species, out of which 18 are spiny, and two may fairly be called hairy. I do not speak of mere pubescence, but of true hairs and spines. Now, out of these 20, 10 are black, two greyish, six brown or brownish, one greyish-green, and only one green. Thus, while green is so preponderating a colour among smooth-skinned or ordinarily pubescent* caterpillars (37 out of the 66 species of butterflies being of this colour), only a single spiny species is thus coloured.

6. Now let us look at these numbers under a different aspect. Out of 66 species 10 are black; and, as we have already seen, all these are spiny or

* "Pubescent" means covered with very short fine hairs.

hairy. The caterpillar of the **Crimson-ringed Butterfly**—a species reputed to have been taken in this country—is stated to be black, and is not hairy or spiny; but, as it has red spots and blue tubercles, and the neck is furnished with a yellow forked appendage, it is probably sufficiently protected. The larva of the **Swallow-tail Butterfly** is also marked with black, and provided with strongly-scented tentacles, which probably serve as a protection.

Again, there are 16 brown species, and of these seven are hairy or spiny.

7. Red and blue are rare colours among caterpillars. Omitting minute dots, we have six species more or less marked with red or orange.* Of these, two are spiny, two hairy, and one protected by scent-emitting tentacles. The orange medio-dorsal line of the Bedford Butterfly† is not very conspicuous, and has been omitted in some descriptions. Blue is even rarer than red; in fact, none of our butterfly larvæ can be said to exhibit this colour.

8. Now let us turn to the moths. I have taken all the larger species, amounting to rather more than 120;‡ out of which 68 are hairy or downy; and

* These are *A. aglaia*, *V. antiopa*, *N. lucina*, *C. alsus*, *P. cratægi*, and *P. machaon*.

† *Cupido alsus*.

‡ The *Hepialidæ*, *Zeuzeridæ*, and *Sesidæ* have been omitted, because these larvæ are all internal or subterranean feeders, and are devoid of any striking colour.

of these 48 are marked with black or grey, 15 brown or brownish, two yellowish-green, one bluish-grey, one striped with yellow and black, and one reddish-grey. There are two yellowish-green hairy species, which might be regarded as exceptions: one, that of the **Five-spotted Burnet-moth**, is marked with black and yellow, and the other* is variable in colour, some specimens of this caterpillar being orange. This last species is also marked with black, so that neither of these species can be considered of the green colour which serves as a protection. Thus, among the larger caterpillars, there is not a single hairy species of the usual green colour. On the other hand, there are 50 species with black or blackish caterpillars, and of these 48 are hairy or downy.

9. In 10 of our larger moths the caterpillars are more or less marked with red. Of these, three are hairy, one is an internal feeder, four have reddish lines, which probably serve for protection by simulating lines of shadow, and one, the Euphorbia Hawk-moth, is inedible. The last, the striped Hawk-moth, is rare, and I have never seen the caterpillar; but to judge from figures, the reddish line and spots would render it, not more, but less conspicuous amongst the low herbage which it frequents.

10. Seven species only of our larger moths have any blue; of these, four are hairy, the other three are

* *Nola albulalis.*

hawk-moths. In one, the Death's Head, the violet colour of the side stripes certainly renders the insect less conspicuous among the flowers of the potato, on which it feeds. In the Oleander Hawk-moth there are two blue patches, which, both in colour and form, curiously resemble the petals of the periwinkle, on which it feeds. In the third species, the small Elephant Hawk-moth, the bluish spots form the centres of the above-mentioned eye-like spots.

11. In one family,* as already mentioned, the caterpillars are very often brown, and closely resemble bits of stick, the similarity being much increased by the peculiar attitudes they assume. On the other hand, the large brown caterpillars of certain Hawk-moths are night feeders, concealing themselves on the ground by day; and it is remarkable that while those species, such as the **Convolvulus Hawk-moth**, which feed on low plants, turn brown as they increase in age and size, others, which frequent trees, and cannot therefore descend to the ground for concealment, remain green throughout life. Omitting these, there are among the larger species, 17 which are brown, of which 12 are hairy, and two have extensile caudal† filaments. The others closely resemble bits of stick, and place themselves in peculiar and stiff attitudes.

* The *Geometridæ*.

† *Extensile*=capable of being extended; *Caudal*=belonging to the tail.

12. And thus, summing up the caterpillars, both of butterflies and moths, out of 88 spiny and hairy species, only one is green,* and even this may not be protectively coloured, since it has conspicuous yellow warts. On the other hand, a very great majority of the black and brown caterpillars, as well as those more or less marked with blue and red, are either hairy or spiny, or have some special protection.

13. Here, then, I think we see reasons, for many at any rate, of the variations of colour and markings in caterpillars, which at first sight seem so fantastic and inexplicable. I should, however, produce an impression very different from that which I wish to convey, were I to lead you to suppose that all these varieties have been explained, or are understood. Far from it; they still offer a large field for study; nevertheless, I venture to think the evidence now brought forward, however imperfectly, is at least sufficient to justify the conclusion that there is not a hair or a line, not a spot or a colour, for which there is not a reason—which has not a purpose or a meaning in the economy of nature.

* *L. sybilla.*

Fig. 21.—White Deadnettle (*Lamium album*).

SECTION IV.—ON FLOWERS AND INSECTS.

I.

1. The flower of the common **White Deadnettle** (fig. 22) consists of a narrow tube, somewhat expanded at the upper end (fig. 23), where the lower lobe of the corolla forms a platform, on each side of which is a small projecting tooth (fig. 23, *m*). The upper portion of the corolla is an arched hood (fig. 23, *co*), under which lie four anthers (*a a*), in pairs, while between them, and projecting somewhat downwards, is the pointed pistil (*st*). At the

lower part, the tube contains honey, and above the honey is a row of hairs almost closing the tube. Now, why has the flower this peculiar form? What regulates the length of the tube? What is the use of this arch? What lessons do these teeth teach

Fig. 22.—Flower of White Deadnettle (*Lamium album*).

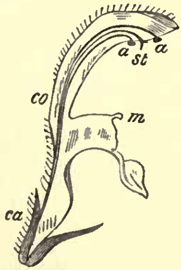


Fig. 23.—Section of the Flower of the White Deadnettle (*Lamium album*).

us? What advantage is the honey to the flower? Of what use is the fringe of hairs? Why does the stigma project beyond the anthers? Why is the corolla white, while the rest of the plant is green?

2. Similar questions may of course be asked with

reference to other flowers. Let us see whether we can throw any light upon them.

Before, however, proceeding further, let me briefly mention the terms used in describing the different parts of a flower.

If we examine a common flower we shall find that

Fig. 24.—Meadow Geranium (*Geranium pratense*).

it consists, firstly, of an outer envelope or *calyx*, sometimes tubular, sometimes consisting of separate leaves called *sepals;* secondly, an inner envelope or *corolla*, which is generally more or less coloured, and which, like the calyx, is sometimes tubular, sometimes composed of separate leaves called

petals; thirdly, of one or more stamens, consisting of a stalk or *filament*, and a head or *anther*, in which the pollen is produced; and fourthly, a *pistil*, which is situated in the centre of the flower, and consists generally of three principal parts: one or more compartments at the base, each containing one or more seeds; the stalk or style; and the *stigma*, which in many familiar instances forms a small head at the top of the style or ovary, and to which the pollen must find its way in order to fertilise the flower.

3. At the close of the last century, Conrad Sprengel, a German schoolmaster, published a valuable work on flowers, in which he pointed out that the forms and colours, the scent, honey, and general structure of flowers, have reference to the visits of insects, which are of importance in transferring the pollen from the stamens to the pistil. This admirable work, however, did not attract the attention it deserved, and remained almost unknown until Mr. Darwin devoted himself to the subject. Our illustrious countryman was the first clearly to perceive that the essential service which insects perform to flowers, consists not only in transferring the pollen from the stamens to the pistil, but in transferring it from the stamens of one flower to the pistil of another. Sprengel had indeed observed in more than one instance that this was the case, but he did not altogether appreciate the importance of the fact.

4. Mr. Darwin, however, has not only made it clear from theoretical considerations, but has also proved it, in a variety of cases, by actual experiment. More recently Fritz Müller has even shown that in some cases pollen, if placed on the stigma of the same flower, has no more effect than so much inorganic dust.

In by far the majority of cases, the relation between flowers and insects is one of mutual advantage. In some plants, however—as, for instance, in our **Common Sundew**—we find a very different state of things, and the plant catches and devours the insects. The first observation on insect-eating flowers was made about the year 1768 by our countryman Ellis. He observed that in a certain North American plant the leaves have a joint in the middle, and thus close over, kill, and actually digest any insect which may alight on them.

5. In our common Sundew (fig. 25) the rounded leaves are covered with hairs, which are swollen and glutinous at the tip. Of these hairs there are on an average about 200 on a full-sized leaf. The tips of the hairs are each surrounded by a drop of an exceedingly viscid solution, which, glittering in the sun, has given rise to the name of the plant. If any object be placed on the leaf, these glandular hairs slowly fold over it, and enclose it. If, for instance, any small insect alights on the leaf it becomes entangled in the glutinous secretion, the glands close over it, their secretion is

increased, and they literally digest their prey. It has been recently shown that plants supplied with insects grow more vigorously than those not so fed. If, on the other hand, a small stone, or any other substance which contains no nourishment, be placed on the leaf, though the hairs at first close over it, they soon open again. It is very

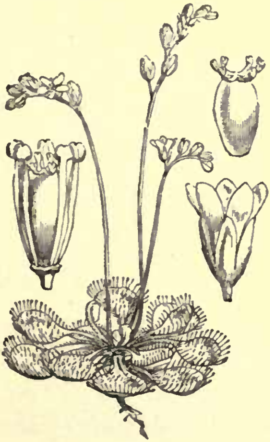


Fig. 25.—COMMON SUNDEW (*Drosera rotundifolia*).

curious that while the glands are so sensitive that an object weighing only $\frac{1}{78740}$th of a grain placed on them is sufficient to cause motion, yet they are "insensible to the weight and repeated blows of drops" of even heavy rain.

6. The Sundew, however, is not our only English insectivorous plant. In the **Butterwort**, which fre-

quents moist places, generally on mountains, the leaves are concave with incurved margins, and the upper surfaces are covered with two sets of glandular hairs. In this case the naturally incurved edges curve over still more if a fly or other insect be placed on the leaf.

7. Another case is that of the **Bladderwort**

Fig. 26.—COMMON BLADDERWORT (*Utricularia vulgaris*).

(fig. 26), an aquatic species, which bears a number of little bags which have been supposed to act as floats. Branches, however, which bear no bladder float just as well as the others, and there seems no doubt that the real use of these little bags is to capture small aquatic animals, which they do in considerable numbers. The bladders, in fact, are on the prin-

ciple of an eel-trap, having an entrance closed with a flap which permits an easy entrance, but effectually prevents the unfortunate victim from getting out again.

8. I will only allude to one foreign case, that of the **Sarracenia.** In this genus some of the leaves are in the form of a pitcher. They secrete a fluid, and are lined internally with hairs pointing downwards. Up the outside of the pitcher there is a line of honey glands, which lure the insects to their destruction. Flies and other insects which fall into this pitcher cannot get out again, and are actually digested by the plant. Bees, however, are said to be scarcely ever caught.

II.

1. Every one knows how important flowers are to insects; every one knows that bees, butterflies, &c., derive the main part of their nourishment from the honey or pollen of flowers, but comparatively few are aware, on the other hand, how much the flowers themselves are dependent on insects. Yet it has, I think, been clearly shown that if insects have been in some respects modified and adapted with a view to the acquirement of honey and pollen, flowers, on the other hand, owe their scent and honey, their form and colour, to the agency of insects. Thus the lines and bands by which so many flowers are ornamented have reference to the position of the honey; and it may be observed that these honey-guides are absent in flowers which open at night, where they of course would not show, and would therefore be useless. Flowers, moreover, which are generally pale—for instance, the **White Lychnis**—open in the evening; while those of a deeper hue, such as the **Red Lychnis**, flower by day.

2. Indeed, it may be laid down as a general rule, that those flowers which are not fertilised by honey-seeking insects—as, for instance, those of the **Dock** (fig. 27), the **Beech**, and most other forest trees—

are small in size, and do not possess either colour, scent, or honey.

Though the pistil is generally surrounded by a row of stamens, there are comparatively few cases in which the pollen of the latter falls directly on the former. On the contrary, this transference is in most cases effected in other ways, generally

Fig. 27.—BROAD DOCK (*Rumex obtusifolius*).

by means of the wind, of insects, or, in some cases, of birds. In the former case, however, by far the greater part of the pollen is wasted; and much more must therefore be produced than in those cases where it is carried by insects.

3. One advantage, of course, is the great economy of pollen. We have not much information on the

subject, but it would seem, from the few observations that have been made, that half a dozen pollen grains are sufficient to fertilise a seed. But in plants in which the pollen is carried by the wind, the chances against any given grain reaching the pistil of another flower are immense. Consequently by far the greater part of the pollen is lost. Every one, for instance, must have observed the clouds of pollen produced by the **Scotch Fir.** In such flowers as the **Pæony** the pollen is carried by insects, and far less therefore is required; yet even here the quantity produced is still large; it has been estimated that each flower produces between 3,000,000 and 4,000,000 grains. The **Dandelion** is more specialised in this respect, and produces far less pollen, about 240,000 grains to each flower; while in the common **Avens** only ten times more pollen is produced than is actually used in fertilisation.

4. It might, however, be at first supposed that where stamens and pistil co-exist in the same flower, the pollen from the one could easily fall on and fertilise the other. And in fact this does occur in some species; but, as we have seen, it is a great advantage to a species that the flower should be fertilised by pollen from a different stock. How then is self-fertilisation prevented?

There are three principal modes.

Firstly, in many plants the stamens and pistil are in separate flowers, sometimes situated on different plants.

Secondly, even when the stamens and pistil are in the same flower, they are in many species not mature at the same time; this was first observed by Sprengel as long ago as 1790; in some cases the stigma has matured before the anthers are ripe, while in other and more numerous cases the anthers have ripened and shed all their pollen before the stigma has come to maturity.

Thirdly, there are many species in which, though the anthers and stigma are contained in the same flower and are mature at the same time, they are so situated that the pollen can hardly reach the stigma of the same flower.

5. The transference of the pollen from one flower to another is, as already mentioned, effected principally either by the wind or by insects.

Wind-fertilised flowers, as a rule, have no colour, emit no scent, produce no honey, and are regular in form. Colour, scent, and honey are the three characteristics by which insects are attracted to flowers.

As a rule, wind-fertilised flowers produce much more pollen than those which are fertilised by insects. This is necessary, because it is obvious that the chances against any given pollen grain reaching the stigma are much greater in the one case than in the other. Every one, as already mentioned, has observed the showers of yellow pollen produced by the Scotch Fir.

6. Again, it is an advantage to wind-fertilised

plants to flower early in the spring before the leaves are out, because the latter would catch much of the pollen, and thus interfere with its access to the stigma. Again, in these plants the pollen is less adherent, so that it can easily be blown away by the wind, which would be a disadvantage in most plants which are fertilised by insects.

Such flowers generally have the stigma more or less branched or hairy, which evidently must tend to increase their chances of catching the pollen.

7. The evidence derivable from the relations of bees and flowers is probably sufficient to satisfy most minds that bees are capable of distinguishing colours, but the fact had not been proved by any conclusive experiments. I therefore tried the following. If you bring a bee to some honey, she feeds quietly, goes back to the hive, stores away her honey, and returns with or without companions for another supply. Each visit occupies about six minutes, so that there are about 10 in an hour, and about 100 in a day. I may add that in this respect the habits of wasps are very similar, and that they appear to be quite as industrious as bees. Perhaps I may give the record of a morning's work of one of my wasps.* She came to the honey at a few minutes after 4 in the morning, and to show how regularly she worked I may give the following extract from my note-book, recording her visits from 6.30 till 12. Thus she—

* In her case the intervals were rather longer than usual.

Came again at 6.29,		and returned at 6.32	
,,	6.41	,,	6.44
,,	6.55	,,	7
,,	7.11	,,	7.15
,,	7.23	,,	7.26
,,	7.37	,,	7.42
,,	7.56	,,	8.3
,,	8.11	,,	8.14
,,	8.20	,,	8.24
,,	8.31	,,	8.34
,,	8.40	,,	8.42
,,	8.50	,,	8.52
,,	8.58	,,	9
,,	9.8	,,	9.11
,,	9.18	,,	9.22
,,	9.30	,,	9.32
,,	9.39	,,	9.40
,,	9.50	,,	9.54
,,	10.1	,,	10.5
,,	10.14	,,	10.17
,,	10.25	,,	10.28
,,	10.37	,,	10.40
,,	10.47	,,	10.51
,,	11	,,	11.6
,,	11.17	,,	11.20
,,	11.34	,,	11.37
,,	11.50	,,	11.53
,,	12.5	,,	12.8

and so on till half-past 7 in the evening. Thus she worked twelve hours like a man, and performed more than 100 journeys to and fro.* This, how-

* Mr. Darwin, in his last work, brought forward some striking evidence how rapidly bees work. They visit, it appears, 20 flowers in a minute, and so carefully do they economise the sunny hours, that in flowers with several nectaries if they find one dry, they do

ever, was in autumn; in summer they make overtime, and work on till late in the evening.

8. I have already mentioned some experiments which show clearly that bees can distinguish colours. They appear fortunately to prefer the same colours as we do. On the contrary, flowers of a livid, yellow, or fleshy colour are most attractive to flies; and moreover, while bees are attracted by odours which are also agreeable to us, flies, as might naturally be expected from the habits of their larvæ, prefer some which to us seem anything but pleasant.

not waste time by examining the others on the same plant. Mr. Darwin watched carefully certain flowers, and satisfied himself that each one was visited by bees at least thirty times in a day. The result is, that even where flowers are very numerous—as, for instance, on heathy plains and in clover fields—every one is visited during the day. Mr. Darwin carefully examined a large number of flowers in such cases, and found that every single one had been visited by bees.

Fig. 28.—COMMON WILLOW HERB (*Epilobium angustifolium*).

III.

1. Among other obvious evidences that the beauty of flowers is useful in consequence of its attracting insects, we may adduce those cases in which the transference of the pollen is effected in different manners in nearly allied plants, sometimes even in the same genus.

Thus, the **Common Mallow** (fig. 29) and **Dwarf Mallow** (fig. 30), which grow in the same localities, and therefore must come into competition, are nevertheless nearly equally common.

In the Common Mallow, however, where the

branches of the stigma are so arranged (fig. 31) that the plant cannot fertilise itself, the petals are large and conspicuous, so that the plant is visited

Fig. 29.—COMMON MALLOW (*Malva sylvestris*).

Fig. 30.—DWARF MALLOW (*Malva rotundifolia*).

by numerous insects; while in the Dwarf Mallow (fig. 32), the flowers of which are comparatively small and rarely visited by insects, the branches of the stigma are elongated, and twine themselves

among the stamens, so that the flower readily fertilises itself.

2. Another interesting case is afforded by the

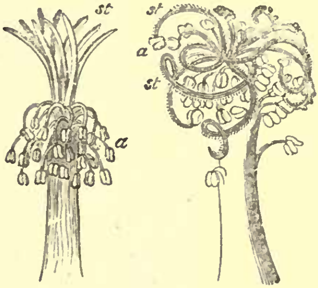


Fig. 31. Fig. 32.

Stamens and Stigmas of the COMMON MALLOW (*Malva sylvestris*) and the DWARF MALLOW (*Malva rotundifolia*).

Fig. 33.—COMMON WILLOW HERB (*Epilobium angustifolium*).

Willow Herbs. The Common Willow Herb (fig. 33) has large purplish flowers in conspicuous heads, and is much frequented by insects; while the

Hoary Willow Herb (fig. 34) has small solitary flowers, and is seldom visited by insects. Now in the former species their visits are necessary, because the stamens ripen and shed their pollen before the pistil, so that the flower is consequently incapable of fertilising itself. In the latter species, on the contrary, the stamens and pistil come to maturity at the same time.

3. Let us take another case, that of certain Gera-

Fig. 34.—HOARY WILLOW HERB (*Epilobium parviflorum*).

niums. In the **Meadow Geranium** (fig. 35), which has a very large flower, all the stamens open, shed their pollen, and wither away, before the pistil comes to maturity. The flower cannot, therefore, fertilise itself, and depends entirely on the visits of insects for the transference of the pollen. In the **Mountain Geranium**, where the flower is not quite so large, all the stamens ripen before the stigma, but the interval is shorter, and the stigma is mature before all the anthers have shed their pollen. It is,

therefore, not absolutely dependent on insects. In the **Dove's-foot Geranium**, which has a still smaller

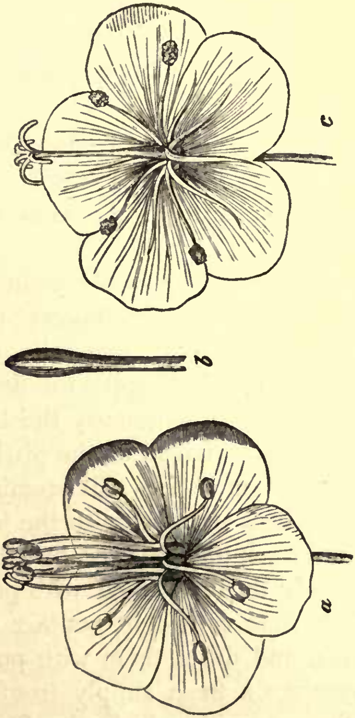


Fig. 35.

MEADOW GERANIUM (*Geranium pratense*).
Young flower.
Five of the stamens are erect.

MEADOW GERANIUM (*Geranium pratense*).
Older flower.
The stamens have retired, and the stigmas are expanded.

flower, five of the stamens come to maturity before the stigma, but the last five ripen simultaneously

with it. Lastly, in the **Small-flowered Geranium**, which is least of all, the stigma ripens even before the stamens. Thus, then, we have a series more or less dependent on insects, from the Meadow Geranium to which they are necessary, to the Small-flowered Geranium which is quite independent of them; whilst the size of the corolla increases with the dependence on insects.

In those species in which self-fertilisation is prevented by the circumstance that the stamens and pistil do not come to maturity at the same time, the stamens generally ripen first.

4. The advantage of this is probably connected with the visits of bees. In those flowers which grow in bunches the lower ones generally open first. Consequently in any given spike the flowers are at first all staminate; subsequently the lower ones, being the older, have arrived at the pistillate stage, while the upper ones are still staminate. Now it is the habit of bees to begin with the lower flowers of a spike and work upwards. A bee, therefore, which has already dusted herself with pollen from another flower, first comes in contact with the pistillate flowers, and dusts them with pollen, after which she receives a fresh supply from the upper staminate flowers, with which she flies to another plant.

5. There are, however, some few species in which the pistil ripens before the stamens. One is our common **Figwort**. Now, why is this?

Probably because the Figwort is one of our few flowers specially visited by wasps, the honey being not pleasing to bees. Wasps, however, unlike bees, generally begin with the upper flowers and pass downwards, and consequently in wasp flowers it is an advantage that the pistil should ripen before the stamens. But though the stamens generally ripen before the pistil, the reverse sometimes occurs. Of this a very interesting case is that of the genus **Aristolochia**. The flower is a long tube, with a narrow opening closed by stiff hairs which point backwards, so that it much resembles an ordinary eel-trap. Small flies enter the tube in search of honey, but from the direction of the hairs it is impossible for them to return. Thus they are imprisoned in the flower, until the stamens have ripened and shed their pollen, by which the flies get thoroughly dusted. Then the hairs of the tube shrivel up, thus releasing the prisoners, who carry the pollen to another flower.

6. Again, in our common **Arums**, the lords-and-ladies of village lanes, the well-known green leaf incloses a central pillar (fig. 36); near the base of which are arranged a number of stigmas (*st* in the accompanying figure), and above them several rows of anthers (*a*). It might be supposed, therefore, that the pollen from the anthers would fall on and fertilise the stigmas. This, however, is not what occurs. In fact the stigmas come to maturity first, and have lost the possibility of fertilisation before

the pollen is ripe. The pollen must therefore be brought by insects, and this is effected by small flies, which enter the leaf, either for the sake of honey or of shelter, and which, moreover, when they have once entered the tube, are imprisoned by the fringe of hairs (*h*). When the anthers

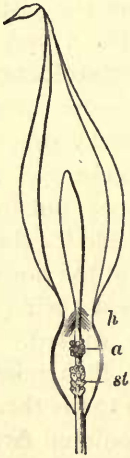


Fig. 36.—Common Arum. Diagrammatic Section.
h, hairs; *a*, anthers; *st*, stigmas.

ripen, the pollen falls on to the flies, which in their efforts to escape get thoroughly dusted with it. Then the fringe of hairs withers, and the flies, thus set free, soon come out, and ere long carry the pollen to another plant.

7. Now let us return to our **White Deadnettle**,

and see how far we can answer the questions which I began by asking.

8. In the first place, the honey attracts insects. If there were no honey, they would have no object in visiting the flower. The bright colour is useful in rendering the flower conspicuous. The platform serves as an alighting stage for bees. The length of the tube has reference to that of their proboscis, and prevents the smaller species from obtaining access to the honey, which would be injurious to the flower, as it would remove the source of attraction for the bees, without effecting the object in view. The upper arch of the flower protects the stamens and pistil, and also presses them firmly against the back of the bee; so that, when the bee alights on the stage and pushes its proboscis down to the honey, its back comes into contact with them. The row of small hairs at the bottom of the tube prevents small insects from creeping down the tube and stealing the honey. Lastly, the small processes on each side of the lower lip are the rudimentary representatives of parts formerly more largely developed, but which, having become useless, have almost disappeared.

9. In the Deadnettle it would appear that the pistil matures as early as the stamens, and that cross-fertilisation is attained by the relative position of the stigma, which, as will be seen in the figure, hangs down below the stamens; so that a bee, bearing pollen on its back from a previous visit to

another flower, would touch the pistil and transfer to it some of the pollen, before coming in contact with the stamens. In other species belonging to the same great group or family of plants, the same object is secured by the fact that the stamens come to maturity before the pistil; they shed their pollen, and shrivel up before the stigma is mature.

IV.

1. Fig. 37 represents a young flower of Sage, in which the stamens (*a a*) are mature, but not the pistil (*p*), which moreover, from its position, is untouched by bees visiting the flower, as shown in

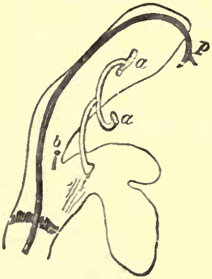


Fig. 37.—SAGE (*Salvia officinalis*). Section of a young flower.

fig. 38. The anthers, as they shed their pollen, gradually shrivel up; while, on the other hand, the pistil increases in length and curves downwards, until it assumes the position shown in fig. 39, *st*, where, as is evident, it must come in contact with any bee visiting the flower, and would touch just that part of the back on which pollen would be deposited by a younger flower. In this manner cross-fertilisation is effectually secured.

2. There are, however, several other curious points

in which the **Sage** differs greatly from the species last described.

The general form of the flower, indeed, is very

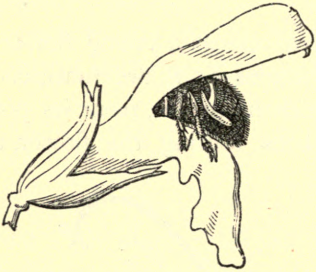


Fig. 38.—SAGE (*Salvia officinalis*) visited by a bee.

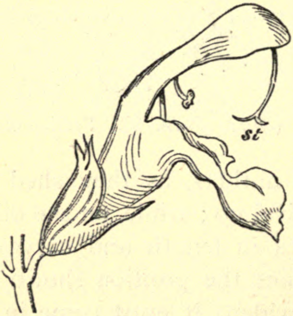


Fig. 39.—SAGE (*Salvia officinalis*). An older flower.

similar. We find again that, as generally in the **Labiates**, the corolla has the lower lip adapted as an alighting board for insects, while the arched

upper lip covers and protects the stamens and pistils.

The arrangement and structure of the stamens is, however, very peculiar and interesting. As in the Deadnettle, they are four in number, but one

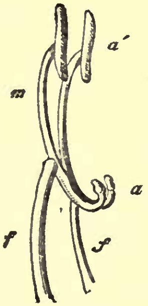


Fig. 40.—Stamens in their natural position.

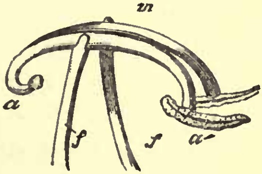


Fig. 41.—Stamens when moved by a bee.

pair is quite rudimentary (fig. 37, *b*). In the other (*a a*) the two anthers, instead of being attached close together at the summit of the filament, are separated by a long movable rod, called a connective (figs. 40, 41, *m*), so that they can play freely on the stalk of the stamen. In a natural position,

this connective is upright, so that the one anther is situated (fig. 37) in the neck of the tube, the other under the arched hood. The lower anther, more-over, is more or less rudimentary. Now, when a bee comes to suck the honey, it pushes the lower anther out of the way with its head; the result of which is that the connective swings round, and the upper fertile anther comes down on to the back of the bee (figs. 38 and 41), and dusts it with honey, just at the place where, in an older flower (fig. 39), it would be touched by the stigma, *st.*

3. At first sight it may seem an objection to this view that some species—as, for instance, the common **Snapdragon**—the flower of which, according to the above-given tests, ought to be fertilised by insects, is entirely closed. A little consideration, however, will suggest the reply. The Snapdragon is especially adapted for fertilisation by humble bees. The stamens and pistil are so arranged that smaller species would not effect the object. It is therefore an advantage that they should be excluded, and in fact they are not strong enough to move the spring. The Snapdragon is, so to say, a closed box, of which the humble bees alone possess the key.

4. The common **Heath** offers us a very ingenious arrangement. The flower is in the form of an inverted bell. The pistil represents the clapper, and projects a little beyond the mouth of the bell. The stamens are eight in number, and form a circle

round it, the anthers being united by their sides into a continuous ring. Each anther has a lateral hole, but as long as they touch one another, the pollen cannot drop out. Each also sends out a long process, so that the ring of anthers is surrounded by a row of spokes. Now when a bee comes to suck the honey, it first touches the end of the pistil, on which it could hardly fail to deposit some pollen, had it previously visited another plant. It would then press its proboscis up the bell, in doing which it would pass between two of the spokes, and pressing them apart, would dislocate the ring of anthers ; a shower of pollen would thus fall from the open cells on to the head of the bee.

5. In many cases the effect of the colouring and scent is greatly enhanced by the association of several flowers in one bunch, or raceme; as, for instance, in the **Wild Hyacinth**, the **Lilac**, and other familiar species. In the great family of **Umbellifera**, this arrangement is still further taken advantage of, as in the common **Wild Chervil** (fig. 42).

In this group the honey is not, as in the flowers just described, situated at the bottom of a tube, but lies exposed, and is therefore accessible to a great variety of small insects. The union of the florets into a head, moreover, not only renders them more conspicuous, but also enables the insects to visit a greater number of flowers in a given time.

6. It might at first be supposed that in such small flowers as these self-fertilisation would be almost

unavoidable. In most cases, however, the stamens ripen before the stigmas.

The position of the honey on the surface of a more or less flat disk renders it much more accessible than in those cases in which it is situated at the end of a more or less long tube. That of the

Fig. 42.—Wild Chervil (*Chærophyllum sylvestris*).

Deadnettle, for instance, is only accessible to certain humble bees; while H. Müller has recorded no less than 73 species of insects as visiting the common Chervil, and some plants are frequented by even a larger number.

7. In the Composites, to which the common **Daisy** and the **Dandelion** belong, the association of flowers

is carried so far, that a whole group of florets is ordinarily spoken of as one flower. The Daisy, for instance, is not really a flower, but a group of little flowers on a single stalk. Let us take, for instance, the common **Feverfew**, or large White Daisy (figs. 43, 44, 45). Each head consists of an outer row of

Fig. 43.—Floret of FEVERFEW (*Chrysanthemum parthenium*), just opened.

pistillate florets or little flowers, in which the tubular corolla terminates on its outer side in a white leaf or ray, which serves to make the flower more conspicuous, and thus to attract insects. The central florets are tubular, and make up the central yellow part of the flower-head. Each of these florets contains a circle of stamens, the upper portions of

which are united at their edges and at the top (fig. 43), so as to form a tube, within which is the pistil. The anthers open inwards, so as to shed the pollen into this box, the lower part of which is

Fig. 44.

Fig. 45.

Fig. 44.—Floret of FEVERFEW (*Chrysanthemum parthenium*), somewhat more advanced.

Fig. 45.—Floret of FEVERFEW (*Chrysanthemum parthenium*), with the stigmas expanded.

formed by the stigma, or upper part of the pistil. As the latter elongates, it presses the pollen against the upper part of the box, which at length is forced open, and the pollen is pushed out (fig. 44). Any insect then alighting on the flower would carry off

some of the pollen adhering to the under side of its body. The upper part of the pistil terminates in two branches (fig. 45, *st*), each of which bears a little brush of hairs. These hairs serve to brush the pollen out of the tube; while in the tube the two branches are pressed close together, but at a later stage they separate, and thus expose the stigmatic surfaces (fig. 45, *st*), on which an insect, coming from a younger flower, could hardly fail to deposit some pollen. The two stigmas in the ray florets of this White Daisy have no brush of hairs; and they would be of no use, as these flowers have no stamens.

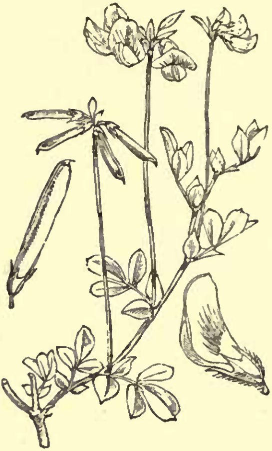


Fig. 46.—Bird's-foot Trefoil (*Lotus corniculatus*).

V.

1. The Leguminosæ, or **Pea-tribe**, present a number of beautiful contrivances. Let us take a common little **Bird's-foot Trefoil** (fig. 46). The petals are five in number; the upper one stands upright, and is known as the standard (fig. 47, *std*); the two lateral ones present a slight resemblance to wings (fig. 47, *w*), while the two lower ones are united along their edges, so as to form a sort of boat, whence they are known as the "keel" (figs. 48, 49, *k*). The stamens, with one exception, are united at their bases, thus forming a tube (figs. 50, 51, *t*), surrounding the pistil, which projects beyond them

Fig. 47.

Fig. 48.

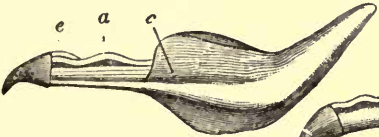


Fig 49.

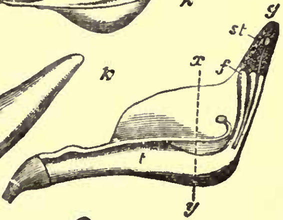


Fig. 50.

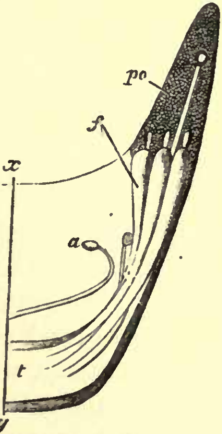


Fig. 51.

Fig. 47.—Flower of BIRD'S-FOOT TREFOIL (*Lotus corniculatus*), seen from the side and in front.
,, 48.—Ditto, after removal of the standard.
,, 49.—Ditto, after removal of the standard and wings.
,, 50.—Ditto, after removal of one side of the keel.
,, 51.—Terminal portion of fig. 50, more magnified.
e, entrance to the honey; *a*, the free stamen; *c*, the place where the wings lock with the keel; *f*, expanded ends of stamens; *x*, filaments of stamens; *g*, tip of keel; *po*, pollen; *st*, stigma.

into a triangular space at the end of the keel. Into this space the pollen is shed (fig. 51, *po*). It must also be observed that each of the wings has a projection (*c*) which locks into a corresponding depression of the keel, so that if the wings are depressed they carry the keel with them. Now when an insect alights on the flower, its weight depresses the wings, and as they again carry with them the keel, the latter slips over the column of stamens, thus forcing some of the pollen out at the end of the keel and against the breast of the insect. As soon as the insect leaves the flower, this resumes its natural position, and the pollen is again snugly protected. The arrangement in the Sweet Pea is very similar, and if the wings are seized by the fingers, and pressed down, this outpumping of the pollen may be easily effected, and the mechanism will then be more clearly understood.

2. It will be observed (fig. 50) that one stamen is separated from the rest. The advantage of this is that it leaves a space through which the proboscis of the bee can reach the honey, which is situated inside the tube formed by the united stamens. In those Leguminosæ which have no honey, the stamens are all united together. Such flowers are, nevertheless, in spite of the absence of honey, visited by insects for the sake of the pollen alone.

In other Leguminosæ—as, for instance, in the **Furze** and the **Broom**—the flower is in a state of tension, but the different parts are, as it were,

locked together. The action of the bee, however, puts an end to this; the flower explodes, and thus dusts the bee with pollen.

It would, however, take too long to refer to the various interesting arrangements by which cross-fertilisation is secured in this great order of plants.

3. It is, indeed, impossible not to be struck by the marvellous variety of contrivances found among flowers, and the light thus thrown upon them, by the consideration of their relations to insects.

I must now call your attention to certain very curious cases, in which the same species has two or more kinds of flowers. Probably in all plants the flowers differ somewhat in size, and I have already mentioned some species in which these differences have given rise to two distinct classes of flowers, one large and much visited by insects, the other small and comparatively neglected. In other species—as, for instance, in some of the **Violets**—these differences are carried much further. The smaller flowers have no smell or honey, the corolla is rudimentary, and, in fact, an ordinary observer would not recognise them as flowers at all. Such small flowers are already known to exist in about 50 genera. Their object probably is to secure, with as little expenditure as possible, the continuance of the species in cases when, from unfavourable weather or other causes, insects are absent; and under such circumstances, as scent, honey, and colour would be of no use, it is an advantage to the

plant to be spared from the effort of their production.

4. As the type of another class of cases in which two kinds of flowers are produced by the same species (though not on the same stock), we may take our common **Cowslips** and **Primroses**. If you

Fig. 52.—Common Cowslip (*Primula veris*).

examine a number of them, you will find that they fall into two distinct series. In some of the flowers the pistil is as long as the tube, and the button-shaped stigma (fig. 53, *st*) is situated at the mouth of the flower, the stamens (*a a*) being halfway down the tube; while, in the other flowers (fig. 54), on the contrary, the anthers are at the mouth of the flower, and the stigma halfway down. The existence of

these two kinds of flowers had long been known, but it remained unexplained until Mr. Darwin devoted his attention to the subject. Now that he has furnished us with the clue, the case is clear enough.

5. An insect visiting a plant of the short-styled form would dust its proboscis at a certain distance from the extremity (fig. 54, *a*), which, when the insect passed to a long-styled flower, would come

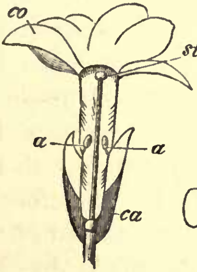
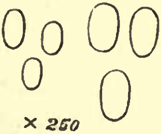


Fig. 53.
Section of the Flower of
PRIMULA.
Long-styled form.



Pollen grains.

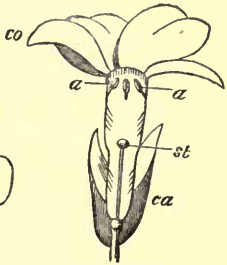


Fig. 54.
Section of the Flower ot
PRIMULA.
Short-styled form.

just opposite to the pistil (fig. 53, *st*). At the same time, the stamens of this second form (fig. 53, *a*) would dust the proboscis at a point considerably nearer to the extremity, which in its turn would correspond to the position of the stigma in the first form (fig. 54, *st*). The two kinds of flowers never grow together on the same stock, and the two kinds of plants generally grow together in nearly equal

proportions. Owing to this arrangement, therefore, insects can hardly fail to fertilise each flower with pollen from a different stock.

6. The two forms differ also in some other respects. In the long-styled form, the stigma (*st*) is globular and rough, while that of the short-styled form is smoother and somewhat depressed. These differences, however, are not sufficiently conspicuous to be shown in the figure. Again, as shown in the figure, the pollen of the long-styled form is smaller than the other, a difference the importance of which is obvious, for each grain of pollen sends out a tube which penetrates the whole length of the style, from the stigma to the base of the flower; and the one has therefore to produce a tube nearly twice as long as that of the other. The careful experiments made by Mr. Darwin have shown that, to obtain the largest quantity of seed, the flowers must be fertilised by pollen from the other form. Nay, in some cases, the flowers produce more seed if fertilised by pollen from another species, than by that from the other form of their own.

7. This curious difference in the Primrose and Cowslip, between flowers of the same species, is found in most species of the genus *Primula*, but not in all.

The Cowslip and Primrose resemble one another in many respects, but the honey they secrete must be very different, for while the Cowslip is habitually

visited during the day by humble bees, this is not the case with the Primrose, which appears to be fertilised almost exclusively by moths.

The genus **Lythrum** affords a still more complex case, for here we have three forms of flowers. The stamens are in two groups: in the one form the pistil projects beyond either of them; in the second form it is shorter than either of them, and in the third it is intermediate in length, so that the stigma lies between the two sets of anthers.

8. Although flowers present us with these beautiful and complex contrivances, whereby the transfer of pollen from flower to flower is provided for, and waste is prevented, yet they appear to be imperfect, or at least not yet perfect in their adaptations. Many small insects obtain access to flowers and rob them of their contents. The Dwarf Mallow can be, and often is, sucked by bees from the outside, in which case the flower derives no advantage from the visit of the insect. In the **Lucerne**, also, insects can suck the honey without effecting fertilisation, and the same flower continues to secrete honey after fertilisation has taken place, and when, apparently, it can no longer be of any use. Fritz Müller has observed that in some plants which are exclusively fertilised by night-flying insects, many of the flowers nevertheless open in the day, and consequently remain sterile. It is of course possible that these cases may be explained away; nevertheless, as both insects and flowers are continually

altering in their structure, and in their geographical distribution, we should naturally expect to find such instances. Water continually tends to find its own level; animals and plants as constantly tend to adapt themselves to their conditions. For it is obvious that any blossom which differed from the form and size best adapted to secure the due transference of the pollen would be less likely to be fertilised than others; while, on the other hand, those richest in honey, sweetest, and most conspicuous, would most surely attract the attention and secure the visits of insects; and thus, just as our gardeners, by selecting seed from the most beautiful varieties, have done so much to adorn our gardens, so have insects, by fertilising the largest and most brilliant flowers, contributed unconsciously, but not less effectually, to the beauty of our woods and fields.

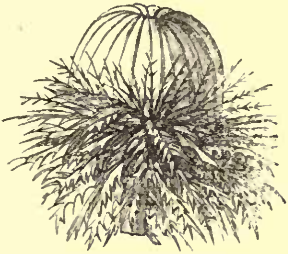


Fig. 55.—Common Carlina (*Carlina vulgaris*).

SECTION V.—ON PLANTS AND INSECTS.

I.

1. In the last chapter I endeavoured to show in a variety of cases how beautifully flowers are constructed, so as to secure their fertilisation by insects. Indeed, neither plants nor insects would be what they are, but for the influence which each has exercised on the other. Some plants, indeed, are altogether dependent on insects for their very existence. We know now, for instance, that certain plants produce no seeds at all, unless visited by insects. Thus, in some of our colonies, the common **Red Clover** sets no seeds on account of the absence of humble bees; for the proboscis of the hive bee is not long enough to effect the object. According to Mr. Belt, the same is the case, and for the same reason, in Nicaragua, with the **Scarlet-Runner.**

But even in those instances in which it is not absolutely necessary, it is an advantage that the flowers should be fertilised by pollen brought from a different stock, and with this object in view, insects are tempted to visit flowers for the sake of the honey and pollen; while the colours and scents are useful in making the flowers more easy to find.

2. Fortunately for us, bees like the same odours as we do; and as the great majority of flowers are adapted for bees, they are consequently sweet; but it might have been otherwise, for flies prefer unpleasant smells, such as those of decaying meat, and other animal substances on which they live as larvæ, and some flowers, consequently, which are fertilised by them, are characterised by very evil odours. Colours also are affected in the same manner, for while bee-flowers (if I may coin such an expression) have generally bright, clear colours, fly-flowers are usually reddish or yellowish brown.

The real use of honey now seems so obvious that it is curious to read the various theories which were once entertained on the subject.

Sprengel was the first to point out the real office of honey, but his views were far from meeting with general assent, and, even as lately as 1833, were altogether rejected by some naturalists.

3. No doubt, however, seems any longer to exist that Sprengel's view is right; and that the true function of honey is to attract insects, and thus to secure cross-fertilisation. Thus, most of the Rose

family are fertilised by insects, and possess nectaries; but, as Delpino has pointed out, the common **Burnet** is wind-fertilised, and possesses no honey. So also the **Maples** are almost all fertilised by insects, and produce honey; but some kinds are wind-fertilised and honeyless. Again, among the **Polygonums**, some species are insect-fertilised and honey-bearing; while, on the other hand, the Docks and some others have no honey, and are fertilised by the wind. At first sight it might appear an objection to this view—and one reason, perhaps, why the earlier botanists missed the true use of honey may have been the fact—that some plants (as, for instance, the **Common Laurel**) secrete honey on other parts than the flowers.

4. Belt and Delpino have, I think, suggested the true function of these extra-floral nectaries.* The former of these excellent observers describes a South American species of **Acacia**: this tree, if unprotected, is apt to be stripped of the leaves by a leaf-cutting ant, which uses them, not directly for food, but, according to Mr. Belt, to grow mushrooms on. The Acacia, however, bears hollow thorns, while each leaflet produces honey in a crater-formed gland at the base, and a small, sweet, pear-shaped body at the tip. In consequence, it is inhabited by myriads of a small ant, which nest in

* I by no means, however, wish to suggest that we as yet fully understand the facts. For instance, the use of the nectary at the base of the leaf of the fern is still quite unexplained.

the hollow thorns, and thus find meat, drink, and lodging all provided for them. These ants are continually roaming over the plant, and constitute a most efficient body-guard, not only driving off the leaf-cutting ants, but, in Belt's opinion, rendering the leaves less liable to be eaten by herbivorous mammalia.

5. I am not aware that any of our English plants are protected in this manner from browsing quadrupeds, but not the less do our ants perform for them a very similar function, by keeping down the number of small insects, which would otherwise rob them of their sap and strip them of their leaves.

Forel watched, from this point of view, a nest of ants. He found that they brought in dead insects, small caterpillars, grasshoppers, cercopis, &c., at the rate of about 28 a minute, or more than 1600 in an hour. When it is considered that the ants work, not only all day, but in warm weather, often all night too, it is easy to see how important a function they fulfil in keeping down the number of small insects.

6. Some of the most mischievous insects, indeed—certain species, for instance, of green fly and scale insect—have turned the tables on the plants, and converted ants from enemies into friends, by themselves developing nectaries and secreting honey, which the ants love. We have all seen the little brown **Garden Ant**, for instance, assiduously running up the stems of plants, to milk their curious little cattle. In this manner, not only do the

aphides and cocci secure immunity from the attacks of the ants, but even turn them from foes into friends. They are subject to the attacks of a species of ichneumon, which lays its eggs in them; and Delpino has seen ants watching over the scale insects with truly maternal vigilance, and driving off the ichneumons whenever they attempted to approach.

7. But though ants are in some respects very useful to plants, they are not wanted in the flowers. The great object is to secure cross-fertilisation; but for this purpose winged insects are almost necessary, because they fly readily from one plant to another, and generally, as already mentioned, confine themselves for a certain time to the same species. Creeping insects, on the other hand, naturally would pass from each floret to the next; and it is of little use to bring pollen from a different flower of the same stock; it must be from a different plant altogether. Moreover, creeping insects, in quitting a plant, would generally go up another close by, without any regard to species. Hence, even to small flowers, which, as far as size is concerned, might well be fertilised by ants, the visits of flying insects are much more advantageous. Moreover, if larger flowers were visited by ants, not only would these deprive the flowers of their honey, without fulfilling any useful function in return, but they would probably prevent the really useful visits of bees. If you touch an ant with a needle or a bristle, she is

almost sure to seize it in her jaws; and if bees, when visiting any particular flowers, were liable to have the delicate tip of their proboscis seized on by the horny jaws of an ant, we may be sure that such a plant would soon be deserted.

8. On the other hand, we know how fond ants are of honey, and how zealously and unremittingly they search for food. How is it, then, that they do not anticipate the bees, and secure the honey for themselves? Kerner has recently published a most interesting book on this subject, and has pointed out a number of ingenious contrivances by which flowers protect themselves from the unwelcome visits of such intruders. The most frequent are the interposition of thick hedges, as it were, in the shape of hairs, which ants cannot penetrate, glutinous parts which they cannot traverse, slippery slopes which they cannot climb, or barriers which close the way.

9. Firstly, then, as regards these hairs. In some respects these are the most effectual protection, since they exclude not only creeping insects, but also other creatures, such as slugs. With this object, it will be observed that the hairs which cover the stalks of so many herbs usually point downwards. A good example of this is afforded, for instance, by a plant (fig. 56) allied to our common **Blue Scabious**. The heads of the common **Carline** (fig. 55), again present a sort of thicket, which must offer an almost impenetrable barrier to ants. Some

species of plants, on the other hand, are quite smooth, excepting just below the flowers. The common but beautiful Cornflower is quite smooth, but the flower-head is bordered with recurved teeth. In this case, neither the stem nor the leaves show a trace of such prickles.

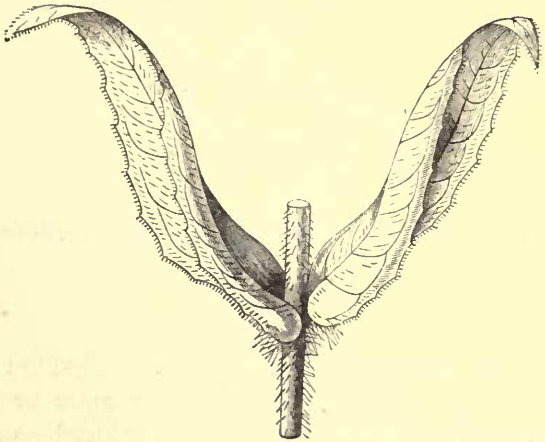


Fig. 56.—*Knautia dipsacifolia*

Fig. 57.—AMPHIBIOUS POLYGONUM (*Polygonum amphibium*).

II.

1. The same consideration throws light on the large number of plants which are more or less glutinous, a condition generally produced—as, for instance, in the flowers of the **Gooseberry** and of **Linnæa borealis** (fig. 58)—by the presence of glandular hairs. Kerner has called attention to a very interesting illustration afforded by a kind of **Polygonum** (fig. 57). In this species the stigma, or top of the pistil, projects about one-fifth of an inch above the flower, so that if ants could obtain access, they would steal the honey without fertilising the flower ; a flying insect, on the contrary,

alighting on the flower, could scarcely fail to touch the stigma.

2. The flowers of this species are of a beautiful rosy colour, and are rich in nectar ; the stamens are short ; the pistil, on the contrary, projects considerably above the corolla. The nectar is not protected by any special arrangement of the flower itself, and is accessible even to very small insects. The stamens ripen before the pistil, and any flying insect, however small, coming from above, would assist in

Fig. 58.—LINNÆA.

cross-fertilisation. Creeping insects, on the contrary, which in most cases would enter from below, would rob the honey without benefiting the plant. The **Amphibious Polygonum**, as its name denotes, grows sometimes in water, sometimes on land. So long, of course, as it grows in water, it is thoroughly protected, and then the stem is smooth ; while, on the other hand, those specimens which live on land throw out certain hairs which terminate in sticky glands, and thus prevent small insects from creeping up to the flowers. In this case, therefore, the

plant is not sticky, except just when this condition is useful. All these viscous plants, as far as I know, have upright or horizontal flowers.

3. On the other hand, where the same object is effected by slippery surfaces, the flowers are often hanging; creeping creatures being thus kept out of them, just as the hanging nests of the weaver-bird are a protection from snakes and other enemies. As instances of this kind I may mention the common **Snowdrop** and the **Cyclamen.**

Many flowers close their petals during rain, and this is obviously an advantage, since it prevents the honey and pollen from being spoilt or washed away. I have elsewhere suggested that the so-called "sleep" of flowers has reference to the habits of insects, on the ground that flowers which are fertilised by night-flying insects would derive no advantage from being open in the day; while, on the other hand, those which are fertilised by bees would gain nothing by being open at night.

4. The **Nottingham Catchfly** (fig. 59) is a very instructive species from this point of view, and indeed illustrates a number of interesting points in the relations between plants and insects. The upper part of the flowering stem is viscid, from which it has derived its English name, the Nottingham Catchfly. This prevents the access of ants and other small creeping insects. Each flower lasts three days, or rather three nights. The stamens are 10 in number, arranged in two sets, the

one set standing in front of the sepals, the other in front of the petals. Like other night flowers, it is white, and opens towards evening, when it also becomes extremely fragrant. The first evening, towards dusk, the five stamens in front of the sepals (fig. 60) grow very rapidly for about two hours, so

Fig. 59.—NOTTINGHAM CATCHFLY (*Silene nutans*).

that they emerge from the flower; the pollen ripens, and is exposed by the bursting of the anther. So the flower remains through the night, very attractive to, and much visited by, moths. Towards three in the morning the scent ceases, the anthers begin to shrivel up or drop off, the filaments turn themselves outwards, so as to be out of the way, while the

petals, on the contrary, begin to roll themselves up, so that by daylight they close the aperture of the flower, and present only their brownish-green undersides to view; which, moreover, are thrown into numerous wrinkles. Thus, by the morning's light, the flower has all the appearance of being faded. It has no smell, and the honey is covered over by the petals. So it remains all day. Towards evening, however, everything is changed. The petals unfold themselves; by eight o'clock the flower is as fragrant as before, the second set of

Fig. 60.—NOTTINGHAM CATCHFLY (*Silene nutans*).

stamens have rapidly grown, their anthers are open, and the pollen again exposed. By morning the flower is again "asleep," the anthers are shrivelled, the scent has ceased, and the petals rolled up as before. The third evening, again the same process occurs, but this time it is the pistil which grows; the long spiral stigmas on the third evening take the position which on the previous two had been occupied by the anthers, and can hardly fail to be dusted by moths with pollen brought from another flower.

5. An objection to the view that the sleep of flowers is regulated by the visits of insects, might be derived from the cases of those flowers which close early in the day, the well-known **Yellow Goats'-beard**, or "**John Go-to-bed-at-Noon**" (fig. 61), for instance; still more such species as the **Nipplewort** or the smooth **Crepis**, which open before six and

Fig. 61.—JOHN GO-TO-BED-AT-NOON, or GOATS'-BEARD (*Tragopogon pratense*).

close again before ten in the morning. Bees, however, are very early risers, while ants come out later, when the dew is off; so that it might be an advantage to a flower which was quite unprotected, to open early for the bees, and close again before the ants were out, thus preserving its honey exclusively for bees.

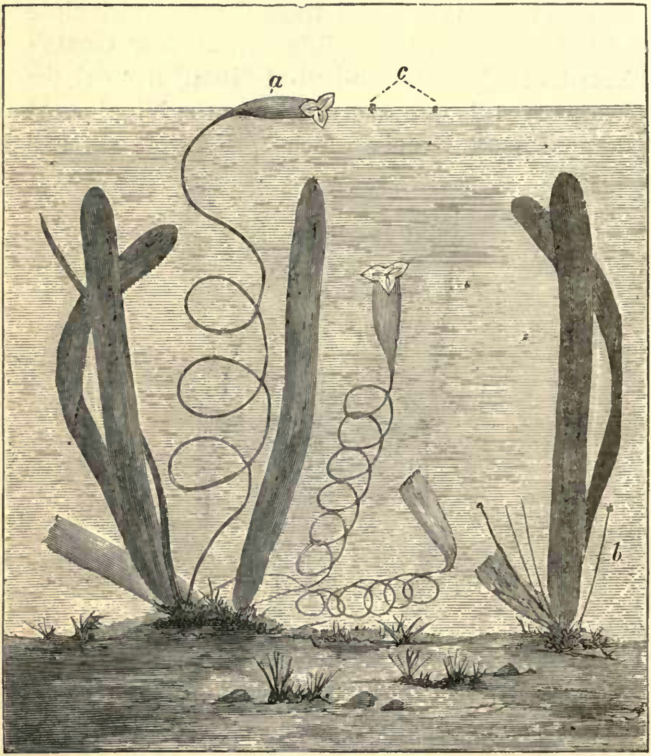


Fig. 62.—VALISNERIA.

a, pistillate flower ; *b*, staminate flower ; *c*, floating pollen.

SECTION VI.—FRUITS AND SEEDS.

I.

1. THOUGH technical terms are very necessary in science, I shall endeavour, as far as I can, to avoid them here. As, however, it will be impossible for me to do so altogether, I will do my best at the commencement to make them as clear as possible.

In order to understand the structure of the seed, we must commence with the flower, to which the seed owes its origin. Now, if you take such a flower as, say a **Geranium**, you will find, as has been already explained, that it consists of the following parts:—Firstly, there is a whorl of green leaves, known as the sepals, and together forming the calyx; secondly, a whorl of coloured leaves, or petals, generally forming the most conspicuous part of the flower, and called the corolla; thirdly, a whorl of organs more or less like pins, which are called stamens; and in the heads, or anthers, of which the pollen is produced. These anthers are in reality modified leaves; in the so-called double flowers, as, for instance, in our **Garden Roses**, they are developed into coloured leaves like those

of the corolla, and monstrous flowers are not unfrequently met with, in which the stamens are green leaves, more or less resembling the ordinary leaves of the plant. Lastly, in the centre of the flower is the pistil, which also is theoretically to be considered as constituted of one or more leaves, each of which is folded on itself, and called a carpel. Sometimes there is only one carpel. Generally the carpels have so completely lost the appearance of leaves, that this explanation of their true nature requires a considerable amount of faith. The base of the pistil is the ovary, composed, as I have just mentioned, of one or more carpels, in which the seeds are developed. I need hardly say that many so-called seeds are really fruits; that is to say, they are seeds with more or less complex envelopes.

2. We all know that seeds and fruits differ greatly in different species. Some are large, some small; some are sweet, some bitter; some are brightly—some dull—coloured, some are good to eat, some poisonous; some spherical, some winged; some covered with bristles, some with hairs; some are smooth, and some very sticky.

We may be sure that there are good reasons for these differences.

3. In the first place, then, during growth, seeds in many cases require protection. This is especially the case with those of an albuminous character. It is curious that so many of those which are luscious when ripe, as the **Peach, Strawberry, Cherry,**

Apple, &c., are stringy, and almost inedible, till ripe. Moreover, in these cases, the fleshy portion is not the seed itself, but only the envelope, so that even if the sweet part is eaten the seed itself remains uninjured.

4. On the other hand, such seeds as the **Hazel**, **Beech**, **Spanish Chestnut**, and innumerable others are protected by a thick, impervious shell, which is especially developed in the **Brazil-nut**, the so-called **Monkey Pot**, the **Cocoa-nut**, and other plants.

In other cases the envelopes protect the seeds, not only by their thickness and toughness, but also by their bitter taste, as, for instance, in the **Walnut**. One genus (*Mucuna*) is remarkable in having the pods covered with stinging hairs.

5. In many cases the calyx, which is closed when the flower is in bud, opens when the flower expands; and then, after the petals have fallen, closes again until the seeds are ripe, when it opens for the second time. This is, for instance, the case with the common **Herb Robert** (fig. 68). In a South European plant allied to the thistles the outer envelopes form an exquisite little cage. Another case, perhaps, is that of *Nigella*, or, as it is sometimes more prettily called, "**Love-in-a-Mist**," of old English gardens.

6. Again, the protection of the seed is in many cases attained by curious movements of the plant itself. In fact, plants move much more than is generally supposed. So far from being motionless,

they may almost be said to be in perpetual movement, though the changes of position are generally so slow that they do not attract attention. This is not, however, always the case. We are all familiar with the **Sensitive Plant**, which droops its leaves when touched. Another species has leaves like those of an Acacia, and all day the leaflets go slowly up and down. There is a sort of pea living in India which has trifoliate leaves, the lateral leaflets being small and narrow ; and these leaflets are perpetually moving round and round, whence the specific name *gyrans*. In this case the object of the movement is quite unknown to us. In *Dionæa*, as already mentioned (p. 116), the leaves form a regular fly-trap. Directly an insect alights on them they shut up with a snap.

7. In a great many cases leaves are said to sleep—that is to say, at the approach of night they change their position, and sometimes fold themselves up, thus presenting a smaller surface for radiation, and being, in consequence, less exposed to cold. Mr. Darwin has proved experimentally that leaves which were prevented from moving suffered more from cold than those which were allowed to assume their natural position. He has observed with reference to the arrowroot plant that, if it has had a severe shock, it cannot get to sleep for the next two or three nights.

8. The sleep of flowers is also probably a case of the same kind. These motions, indeed, have but

an indirect reference to our present subject. On the other hand, in the **Dandelion** the flower-stalk is upright while the flower is expanded, a period which lasts for three or four days ; it then lowers itself, and lies close to the ground for about twelve days while the fruits are ripening, and then rises again when they are mature. In the **Cyclamen** the stalk curls itself up into a beautiful spiral after the flower has faded.

The flower of the little **Linaria** of our walls pushes out into the light and sunshine, but as soon as it is fertilised it turns round and endeavours to find some hole or cranny in which it may remain safely ensconced until the seed is ripe.

9. In some water-plants the flower expands at the surface, but after it is faded retreats again to the bottom. This is the case, for instance, with the **Water Lilies** and several other aquatic plants. In **Valisneria**, again, as already mentioned, the pistillate flowers (fig. 62, *a*) are borne on long stalks, which reach to the surface of the water, on which the flowers float. The staminate flowers (fig. 62, *b*), on the contrary, have short straight stalks, from which, when mature, the pollen (fig. 62, *c*) detaches itself, rises to the surface, and, floating freely on it, is wafted about, so that it comes in contact with the pistillate flowers. After fertilisation, however, the long stalk coils up spirally, and thus carries the ovary down to the bottom, where the seeds can ripen in greater safety.

Fig. 63.—Hairy Bittercress (*Cardamine hirsuta*).

II.

1. The next points to which I will direct your attention are the means of dispersion possessed by many seeds. Farmers have found by experience that it is not desirable to grow the same crop in the same field year after year, because the soil becomes more or less exhausted. In this respect therefore the powers of dispersion possessed by many seeds are a great advantage to the species. Moreover, they are also advantageous in giving the seed a chance of germinating in new localities suitable to the requirements of the species. Thus, one com-

mon European species has rapidly spread over the whole of South Africa, the seeds, which are covered with hooked spines, being carried in the wool of sheep.

2. There are a great many cases in which plants possess powers of movement directed to the dissemination of the seed. Thus, there are some funguses which grow underground, but eventually come up to the surface of the ground, split open and shed their spores* in the form of dust.

I have already referred to the case of the common **Dandelion.** Some plants, as we shall see, even sow their seeds in the ground, but these cases will be referred to later on.

3. In other cases the plant throws its own seeds to some little distance. This is the case with the common **Hairy Bittercress** (fig. 63), a little plant, I do not like to call it a weed, six or eight inches high, which comes up abundantly on any vacant spot in our kitchen gardens or shrubberies. The seeds are contained in a pod which consists of three parts, a central membrane and two side walls. When the pod is ripe the walls are much stretched. The seeds are loosely attached to the central piece by short stalks. Now, when the proper moment has arrived, the outer walls are kept in place by a delicate membrane only just strong enough to

* These are tiny seed-like bodies, but are termed "spores" by botanists, because in some important points they differ from true seeds.

resist the tension. The least touch, for instance a puff of wind blowing the plant against a neighbour, detaches the outer wall, which suddenly rolls itself up, generally with such force as to fly from the plant, thus jerking the seeds to a distance of several feet.

4. In the common **Violets**, besides the coloured flowers, there are others in which the corolla is either absent or imperfectly developed. The stamens also are small, but contain pollen, though less than in the coloured flowers. In the autumn large numbers of these curious flowers are produced. When very young they look like an ordinary flower-bud (fig. 64, *a*), the central part of the flower being entirely covered by the sepals, and the whole having a triangular form. When older (figs. 64 and 65, *b*) they look at first sight like an ordinary seed capsule, so that the bud seems to pass into the capsule without the flower stage. The **Pansy Violets** do not possess these interesting flowers. In the **Sweet Violet** and **Hairy Violet** (fig. 64) they may easily be found by searching among the leaves nestling close to the ground. It is often said that the plants actually force these capsules into the ground, and thus sow their own seeds. I have not, however, found this to be the case; though, as the stalk lengthens, and the point of the capsule turns downwards, if the earth be loose and uneven, it will no doubt sometimes so

happen. When the seeds are fully ripe the capsule opens by three valves and allows them to escape.

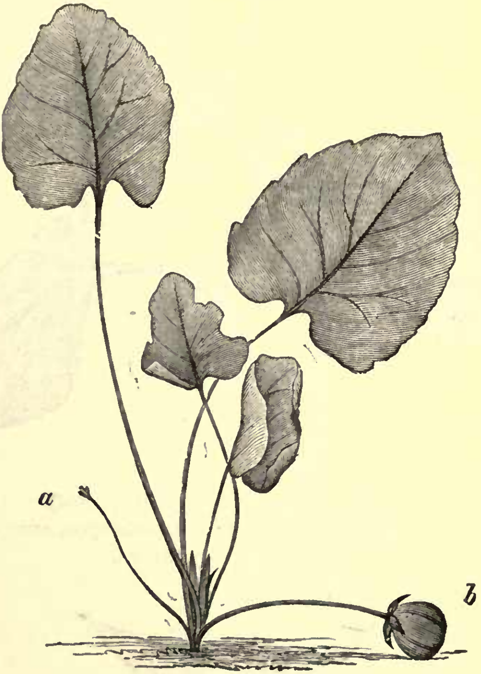


Fig. 64.—HAIRY VIOLET (*Viola hirta*).
a, young bud; *b*, ripe seed capsule.

5. In the **Dog Violet** (fig. 65) the case is very different. The capsules are less fleshy, and, though hanging down when young, at maturity they erect themselves (fig. 65, *c*), stand up boldly above the

Fig. 65.—Dog Violet (*Viola canina*).
a, bud ; *b*, bud more advanced ; *c*, capsule open, some of the seeds are already thrown.

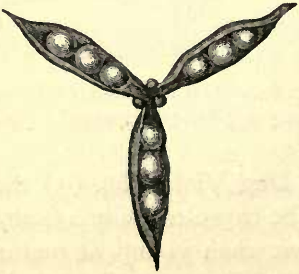


Fig. 66.—Dog Violet. Seed-vessel open and showing seeds.

rest of the plant, and open by the three equal valves (fig. 66), resembling an inverted tripod. Each valve contains a row of three, four, or five brown, smooth, pear-shaped seeds, slightly flattened at the upper, wider end. Now the two walls of each valve, as they become drier, contract, and so approach one another, thus tending to squeeze out the seeds. These resist some time; but at length

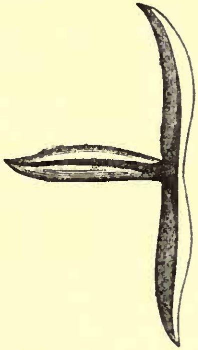


Fig. 67.—Dog Violet. Seed-vessel after ejecting the seeds.

the attachment of the seed to its base gives way, and it is ejected several feet, this being no doubt much facilitated by its form and smoothness. I have known even a gathered specimen throw a seed nearly 10 feet. Fig. 67 represents a capsule after the seeds have been ejected.

6. Now we naturally ask ourselves what is the reason for this difference between the species of violets; why does the Sweet Violet conceal its cap-

sules among the moss and leaves on the ground, while the Dog Violet and others raise theirs boldly above their heads and throw the seeds to seek their fortune in the world? If this arrangement be best for the Dog Violet, why has not the Sweet Violet also adopted it? The reason is, I believe, to be found in the different mode of growth of these two species. The Dog Violet is a plant with an elongated stalk, and it is easy therefore for the capsule to raise itself above the grass and other low herbage among which violets grow. The Sweet Violet, on the contrary, has, in ordinary parlance, no stalk, and the leaves are radical, *i.e.*, rising from the root. This is at least the case apparently, though, botanically speaking, they rise at the end of a short stalk. Now, under these circumstances, if the Sweet Violet attempted to shoot its seeds, the capsule not being sufficiently elevated, the seeds would merely strike against some neighbouring leaf, and immediately fall to the ground. Hence, I think, we see that the arrangement of the capsule in each species is that which is most suitable to the general habit of the plant.

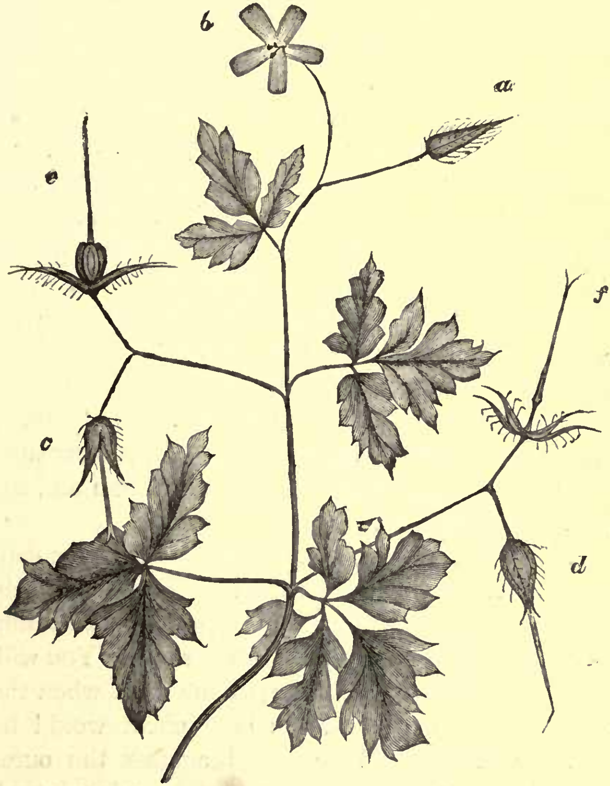


Fig. 68.—Herb-Robert Geranium (*Geranium Robertianum*). *a*, bud; *b*, flower; *c*, flower after the petals have fallen; *d*, flower with seeds nearly ripe; *e*, flower with ripe seeds; *f*, flower after throwing seeds.

III.

1. In the true Geraniums again, as for instance, in the **Herb Robert** (fig. 68), after the flower has faded,

the central axis gradually lengthens (fig. 68, *c d*). The seeds, five in number, are situated at the base of the column, each being enclosed in a capsule, which terminates upwards in a rod-like portion, which at first forms part of the central axis, but gradually detaches itself. When the seeds are ripe the ovary raises itself into an upright position (fig. 68, *e*); the outer layers of the rod-like termination of the seed-capsule come to be in a state of great tension, and eventually (fig. 70) detach the rod with a jerk, and thus throw the seed some little distance. Fig. 68, *f*, represents the central rod after the seeds have been thrown. In some species, as for instance in the **Cut-leaved Geranium** (fig. 69), the capsule-rod remains attached to the central column and the seed only is ejected.

2. It will, however, be remembered that the capsule is, as already observed, a leaf folded on itself, with the edges inwards, and in fact, in the Geranium, the seed-chamber opens on its inner side. You will, therefore, naturally observe to me that when the carpel bursts outwards, the only effect would be that the seed would be forced against the outer wall of the carpel, and that it would not be ejected, because the opening is not on the outer but on the inner side. Your remark is perfectly just, but the difficulty has been foreseen by our Geraniums, and is overcome by them in different ways. In some species, as for instance in the Cut-leaved Geranium, a short time before the opening of the pods, the

seed-chamber places itself at right angles to the pillar (fig. 69, *a*). The edges then separate, but they are provided with a fringe of hairs, just strong enough to retain the seed in its position, yet sufficiently elastic to allow it to escape when the carpels

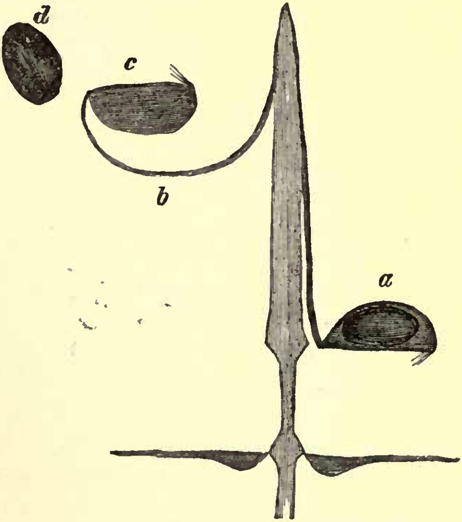


Diagram.

Fig. 69.—THE CUT-LEAVED GERANIUM.

just before throwing seed; *b*, just after throwing seed; *c*, the capsule still attached to the rod; *d*, the seed.

burst away, remaining attached, however, to the central pillar by their upper ends (fig. 69, *c*).

3. In the common Herb Robert (fig. 68 and 70), and some other species, the arrangement is somewhat different. In the first place the whole carpel springs

away (fig. 70, *b* and *c*). The seed-chamber (fig. 70, *c*) detaches itself from the rod of the carpel (fig. 70, *b*), and when the seed is flung away remains attached to it. Under these circumstances it is

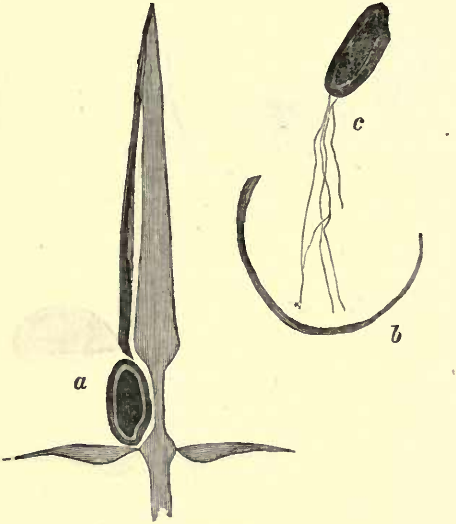


Diagram.
Fig. 70.—HERB ROBERT.
a, just before throwing the seed; *b*, the rod; *c*, the seed enclosed in the capsule.

unnecessary for the chamber to raise itself from the central pillar, to which accordingly it remains close until the moment of disruption (fig. 70, *a*). The seed-chamber is moreover held in place by a short tongue which projects a little way over its base;

while, on the other hand, the lower end of the rod passes for a short distance between the seed-capsule and the central pillar. The seed-capsule has also near its apex a curious tuft of silky hair (fig. 70, *c*), the use of which I will not here stop to discuss. As the result of all this complex mechanism the seeds when ripe are flung to a distance which is

Fig. 71.—WOOD VETCH (*Vicia sylvatica*).

surprising when we consider how small the spring is. In their natural abode it is almost impossible to find the seeds when once thrown. I therefore brought some into the house and placed them on my billiard table. They were thrown from one end completely over the other, in some cases more than 20 feet.

4. Some species of **Vetch** (fig. 71), again, and the

common **Broom**, throw their seeds, owing to the elasticity of the pods, which, when ripe, open suddenly with a jerk. Each valve of the pod contains a layer of woody cells, which, however, do not pass straight up the pod, but are more or less inclined to its axis (fig. 72). Consequently, when the pod

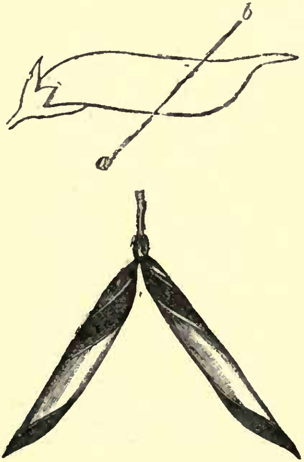


Fig. 72.—Pod of the BUSH VETCH.
The line *a b* shows the direction of the woody fibres.

bursts it does not, as in the case of the Bittercress, roll up like a watch-spring, but twists itself more or less like a corkscrew.

5. I have mentioned these species because they are some of our commonest wild flowers, so that during the summer and autumn we may, in almost any walk, observe for ourselves this innocent artillery.

There are, however, many other more or less similar cases. Thus the **Squirting Cucumber**, a common plant in the south of Europe, and one grown in some places for medicinal purposes, effects the same object by a totally different mechanical arrangement. The fruit is a small cucumber (fig. 73), and when ripe it becomes so gorged with fluid that it is

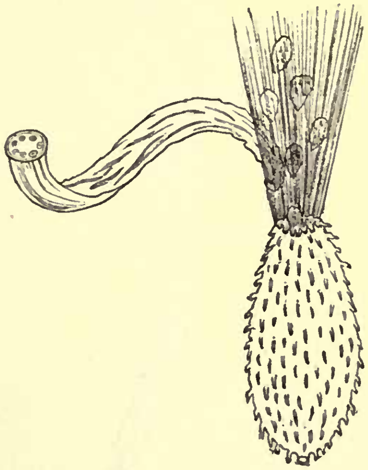


Fig. 73.—Fruit of the SQUIRTING CUCUMBER.

in a state of great tension. In this condition a very slight touch is sufficient to detach it from the stalk, when the pressure of the walls ejects the contents, throwing the seed some distance. In this case of course the contents are ejected at the end by which the cucumber is attached to the stalk. If any one

touches one of these ripe fruits, they are often thrown with such force as to strike him in the face.

6. Even those species which do not eject their seeds often have them so placed with reference to the capsule that they only leave it if swung or jerked by a high wind. In the case of trees, even seeds

Fig. 74.—POPPY-HEAD.

with no special adaptation for dispersion must in this manner be often carried to no little distance; and to a certain, though less extent, this must hold good even with herbaceous plants. It throws light on the fact that in so many plants with small, heavy

seeds, the capsules open, not at the bottom, as one might perhaps have been disposed to expect, but at the top. A good illustration is afforded by the well-known case of the common **Poppy** (fig. 74), in which the upper part of the capsule presents a series of little doors (fig. 74, *a*), through which, when the plant is swung by the wind, the seeds come out one by one. The little doors are protected from rain by overhanging eaves, and are even said to shut of themselves in wet weather. The **Bellflowers** (*Campanula*) are also interesting from this point of view, because some species have the capsules pendent, some upright, and those which are upright open at the top, while those which are pendent do so at the base.

IV.

1. In other cases the dispersion is mainly the work of the seed itself. In some of the lower plants, as, for instance, in many seaweeds, and in some fresh-water plants allied to them, the spores* are covered by vibratile hairs, and actually swim about in the water, like microscopic animals, till they have found a suitable spot on which to grow. Nay, so much do the spores of some seaweeds resemble animals, that they are provided with a red "eye-spot" as it has been called, which, at any rate, seems so far to deserve the name that it appears to be sensitive to light. This mode of progression is, however, only suitable to water plants. One group of small, low-organized plants develops among the spores a number of cells with spirally thickened walls, which, by their contractility, are supposed to disseminate the spores.

2. In much more numerous cases, seeds are carried by the wind. For this of course it is desirable that they should be light. Sometimes this object is attained by the character of the tissues themselves, sometimes by the presence of empty spaces. Thus,

* Speaking botanically, these are not true seeds, but rather moving buds.

in the **Lamb's Lettuce,*** the fruit contains three cells, each of which would naturally be expected to contain a seed. One seed only, however, is developed, but the two cells which contain no seed actually become larger than the one which alone might, at first sight, seem to be normally developed. We may be sure from this that they must be of some use, and, from their lightness, they probably enable the wind to carry the seed to a greater distance than would otherwise be the case.

3. In other instances the plants themselves, or parts of them, are rolled along the ground by the wind. An example of this is afforded, for instance, by a kind of Australian grass, in which the mass of flowers, forming a large round head, is thus driven for miles over the dry sands until it comes to a damp place, when it expands and soon strikes root.

So, again, the "**Rose of Jericho,**" a small annual with rounded pods, which frequents sandy places in Egypt, Syria, and Arabia, when dry, curls itself up into a ball or round cushion, and is thus driven about by the wind until it finds a damp place, when it uncurls, the pods open, and sow the seeds.

4. These cases, however, in which seeds are rolled by the wind along the ground are comparatively rare. There are many more in which seeds are wafted through the air. If you examine the fruit of a **Sycamore**, you will find that it is provided with a wing-like expansion, in consequence of which, if

* *Valerianella.*

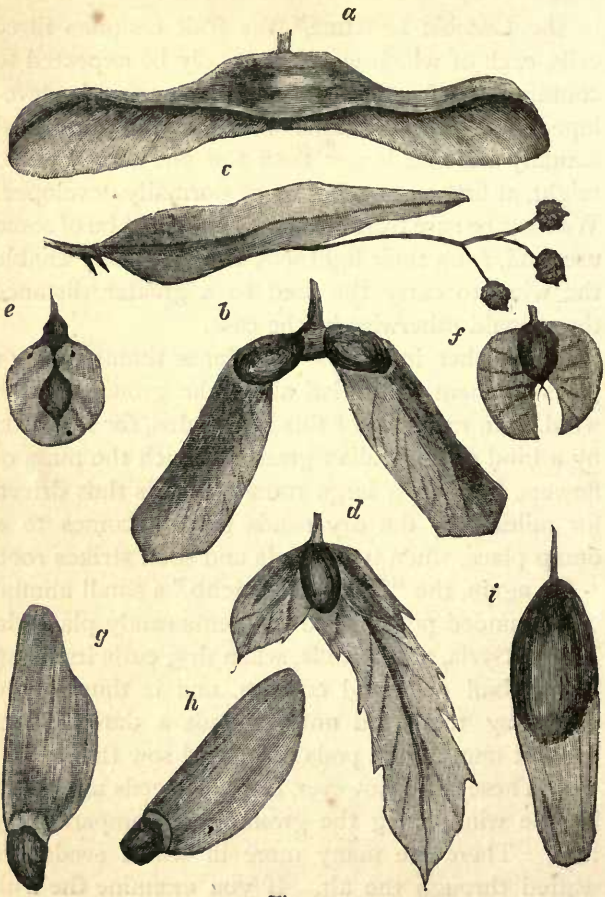


Fig. 75.
Seeds or Fruits.
a, maple ; *b*, sycamore ; *c*, lime ; *d*, hornbeam ; *e*, elm ; *f*, birch ; *g*, pine ; *h*, fir ; *i*, ash.

there is any wind when it falls, it is, though rather heavy, blown to some distance from the parent tree. Several cases are shown in fig. 75; for instance, the **Maple** (*a*), **Sycamore** (*b*), **Hornbeam** (*d*), **Elm** (*e*), **Birch** (*f*), **Pine** (*g*), **Fir** (*h*), and **Ash** (*i*), while in the **Lime** (*c*) the whole bunch of fruits drops together, and the "bract," as it is called, or leaf of the flower-stalk, serves the same purpose.

In a great many other plants the same result is obtained by flattened and expanded edges. Among our common wild plants we find winged fruits in the **Dock** (fig. 27) and in the common **Parsnip**. But though in these cases the object to be obtained—namely, the dispersion of the seed—is effected in a similar manner, there are differences which might not at first be suspected. Thus in some cases, as, for instance, in the **Pine**, it is the seed itself which is winged; in *Thlaspi arvense* it is the pod; in one* leguminous plant the pod breaks up into segments, each of which is winged; in another† the extremity of the pod is expanded into a flattened wing; lastly, in the **Lime** (fig. 75), as already mentioned, the fruits drop off in a bunch, and the leaf at the base of the common flower-stalk, or "bract," as it is called, forms the wing.

6. Another mode, which is frequently adopted, is the development of long hairs. Sometimes, as in **Clematis** and **Anemone**, these hairs take the form of a long feathery awn. In others the hairs form

* *Entada.* † *Nissolia.*

a tuft or crown, which botanists term a "pappus." Of this the **Dandelion** and **John Go-to-Bed-at-Noon**, so called from its habit of shutting its flowers about mid-day, are well-known examples. Tufts of hairs, which are themselves sometimes feathered, are developed in a great many flowers allied to the Dandelion, though some—as, for instance, the **Daisy** and **Lapsana**—are without them; in some very interesting species, of which the common Hawkbit of our lawns and meadows is an example, there are two kinds of fruits, as shown in fig. 76, *b*, one with a pappus and one without. The former are adapted to seek "fresh fields and pastures new," while the latter stay and perpetuate the race at home.

7. A more or less similar pappus is found among various English plants—in the **Willow Herb** (figs. 28 and 76, *a*), **Hawkbit** (fig. 76, *b*), **Tamarix** (fig. 76, *c*), **Willow** (fig. 76, *d*), **Cotton Grass** (fig. 76, *e*), and **Bullrush** (fig. 76, *f*); while in exotic species there are many other cases—as, for instance, the beautiful Oleander. As in the wings, so also in that of the pappus, it is by no means always the same part of the plant which develops into the crown of hairs.

8. In other cases seeds are wafted by water. Of this the **Cocoa-nut** is one of the most striking examples. The seeds retain their vitality for a considerable time, and the loose texture of the husk protects them and makes them float. Every one knows that the Cocoa-nut is one of the first

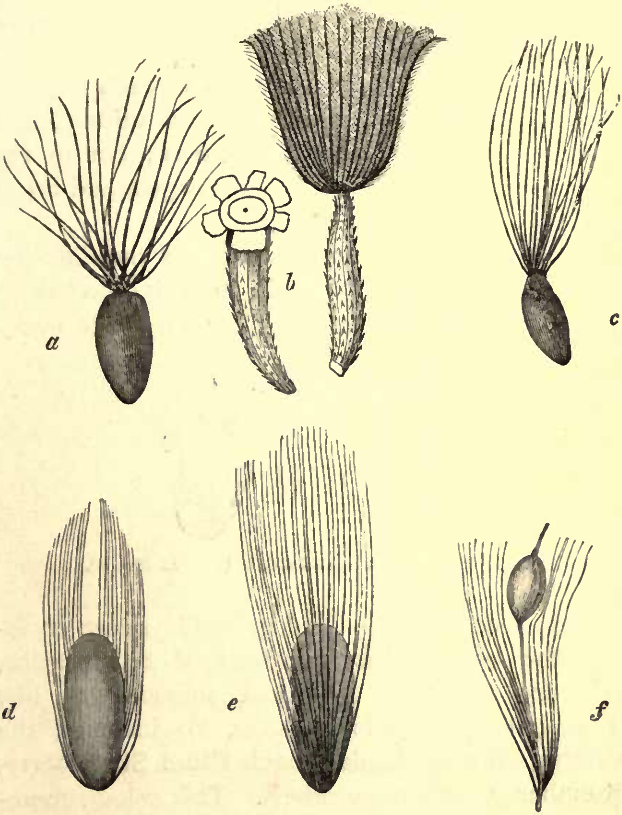


Fig. 76.

Seeds or Fruits.

a, willow herb (*Epilobium*); *b*, two forms of seed of hawkbit; *c*, tamarix; *d*, willow (*Salix*); *e*, cotton grass (*Eriophorum*); *f*, bullrush (*Typha*).

plants to make its appearance on coral islands, and it is, I believe, the only palm which is common to both hemispheres.

The seeds of the common **Duckweeds** (fig. 77) sink to the bottom of the water in autumn, and remain there throughout the winter; but in the spring they rise up to the surface again and begin to grow.

9. In a very large number of cases the diffusion of seeds is effected by animals. To this class belong the fruits and berries. In them an outer fleshy

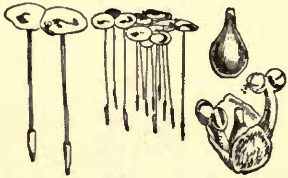


Fig. 77.—Lesser Duckweed (*Lemna minor*).

portion becomes pulpy, and generally sweet, enclosing the seeds. It is remarkable that such fruits, in order, doubtless, to attract animals, are, like flowers, brightly coloured—as, for instance, the **Cherry, Currant, Apple, Peach, Plum, Strawberry, Raspberry**, and many others. This colour, moreover, is not present in the unripe fruit, but is rapidly developed at maturity. In such cases the actual seed is generally protected by a dense, sometimes almost stony, covering, so that it escapes digestion, while its germination is perhaps hastened by the

heat of the animal's body. It may be said that the skin of apple and pear pips is comparatively soft; but then they are embedded in a stringy core, which is seldom eaten.

These coloured fruits form a considerable part of the food of monkeys in the tropical regions of the earth, and we can, I think, hardly doubt that these animals are guided by the colours, just as we are, in selecting the ripe fruit.

10. In these instances of coloured fruits, the fleshy edible part more or less surrounds the true seeds; in others the actual seeds themselves become edible. In the former the edible part serves as a temptation to animals; in the latter it is stored up for the use of the plant itself. When, therefore, the seeds themselves are edible they are generally protected by more or less hard or bitter envelopes, for instance the **Horse Chestnut**, **Beech**, **Spanish Chestnut**, **Walnut**, &c. That these seeds are used as food by squirrels and other animals is, however, by no means necessarily an evil to the plant, for the result is that they are often carried some distance and then dropped, or stored up and forgotten, so that, by this means, they get carried away from the parent tree.

11. In another class of instances, animals, unconsciously or unwillingly, serve in the dispersion of seeds. These cases may be divided into two classes, those in which the fruits are provided with hooks, and those in which they are sticky. To the

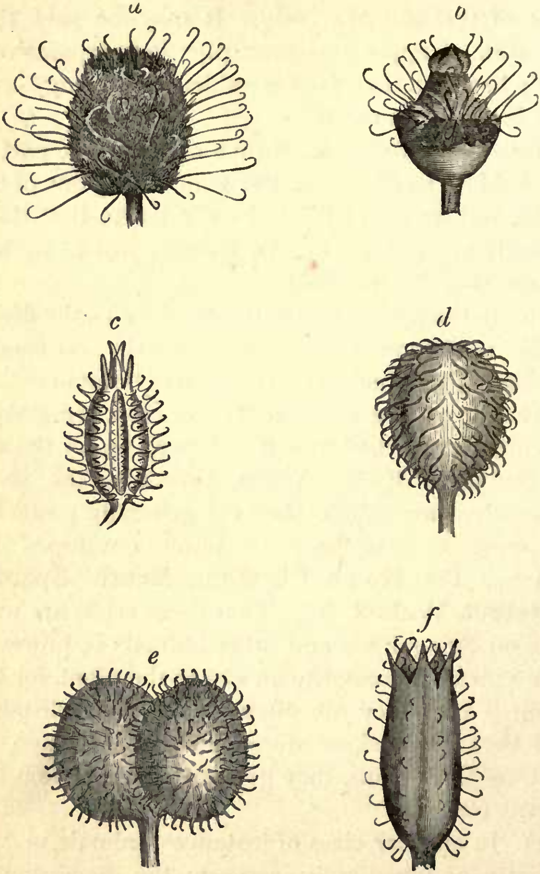


Fig. 78.

Seeds or Fruits.

a, burdock (*Lappa*); *b*, agrimony (*Agrimonia*); *c*, bur parsley (*Caucalis*); *d*, enchanter's nightshade (*Circæa*); *e*, cleavers (*Galium*); *f*, forget-me-not (*Myosotis*).

Fig. 79.
Fruits.
a, *Harpagophyton procumbens* (natural size); *b*, *Martynia proboscidea* (natural size).

first class belong, among our common English plants, the **Burdock** (fig. 78, *a*); **Agrimony** (fig. 78, *b*); the **Bur Parsley** (fig. 78, *c*); **Enchanter's Nightshade** (fig. 78, *d*); **Goose Grass** or **Cleavers** (fig. 78, *e*); and some of the **Forget-me-nots** (fig. 78, *f*). The hooks, moreover, are so arranged as to promote the removal of the fruits. In all these species the hooks, though beautifully formed, are small; but in some foreign species they become truly formidable. Two of the most remarkable are represented above,—*Martynia proboscidea* (fig. 79, *b*) and *Harpagophyton procumbens* (fig. 79, *a*). *Martynia* is a plant of Louisiana, and if its fruits once get hold of an animal it is most difficult to remove them. *Harpagophyton* is a South African genus. The fruits are most formidable, and are said sometimes even to kill lions. They roll about over the dry plains, and if they attach themselves to the skin, the wretched animal tries to tear them out, and sometimes getting them into its mouth perishes miserably.

V.

1. The cases in which the diffusion of fruits and seeds is effected by their being sticky are less numerous, and we have no well-marked instance among our native plants. The common **Plumbago** of South Europe is a well-marked case. There are comparatively few cases in which the same plant uses more than one of these modes of promoting the dispersion of its seeds, still there are some such instances. Thus, in the common Burdock the seeds have a pappus, while the whole flower-head is provided with hooks which readily attach themselves to any passing animal.

2. But perhaps it will be said that I have picked out special cases; that others could have been selected which would not bear out, or perhaps would even negative, the inferences which have been indicated; that I have put "the cart before the horse;" that the Ash fruit has not a wing in order that it may be carried by the wind, nor the Burdock hooks that the heads may be transported by animals, but that, happening to have wings and hooks, these seeds are thus transported. Now, doubtless there are many points connected with seeds which are as yet unexplained; in fact, it is partly because

this is so that I have been anxious to direct attention to the subject. Still, I believe the general explanations which have been given by botanists will stand any test.

3. Let us take, for instance, seeds formed on the same type as that of the **Ash**—heavy fruits, with a long wing. Now, such a fruit would be of little use to low herbs. If, however, the wing was accidental—if it were not developed to serve as a means of dispersion—it would be as likely to occur on low plants and shrubs as on trees. Let us, then, consider on what kind of plants these fruits are found. They occur on the **Ash**, **Maple**, **Sycamore**, **Hornbeam**, **Pine**, **Fir**, and **Elm**; while the **Lime**, as we have seen, has also a leaf attached to the fruits which answers the same purposes. Seeds of this character therefore occur on a large proportion of our forest trees, and on them alone. But more than this: I have taken one or two of the most accessible works in which seeds are figured. I find 30 genera, belonging to 21 different natural orders, figured as having seeds or fruits of this form. They are all trees or climbing shrubs, not one being a low herb.

4. Let us take another case, that of the plants in which the dispersion of the seeds is effected by means of hooks. Now, if the presence of these hooks were, so to say, accidental and the dispersion merely a result, we should naturally expect to find some species with hooks in all classes of plants.

They would occur, for instance, among trees and on water-plants. On the other hand, if they are developed that they might adhere to the skin of quadrupeds, then, having reference to the habits and size of our British quadrupeds, it would be no advantage for a tree or for a water-plant to bear hooked seeds. Now, what are the facts? There are about thirty English species in which the dispersion of the seeds is effected by means of hooks, but not one of these is aquatic, nor is one of them more than four feet high. Nay, I might carry the argument further. We have a number of minute plants which lie below the level at which seeds would be likely to be entangled in fur. Now, none of these, again, have hooked seeds or fruits. It would seem that, in the history of the earth also, the appearance of the families of plants in which the fruits or seeds are provided with hooks coincided with that of the land quadrupeds.

5. Again, let us look at it from another point of view. Let us take our common forest trees, shrubs, and tall climbing plants; not, of course, a natural or botanical group, for they belong to a number of different families, but a group characterised by attaining to a height of, say, over 8 feet. We will in some cases only count genera; that is to say, we will count all the willows, for instance, as one. These trees and shrubs are plants with which you are all familiar, and in this country are about 33 in number. Now, of these 33 no less than 18 have

edible fruits or seeds, such as the Plum, Apple, Arbutus, Holly, Hazel, Beech, and Rose; three have seeds which are provided with feathery hairs; and all the rest, namely, the Lime, Maple, Ash, Sycamore, Elm, Hop, Birch, Hornbeam, Pine, and Fir, are provided with wings. Moreover, as will be seen by the following table, the lower trees and shrubs, such as the Cornel, Guelder Rose, Rose, Thorn, Privet, Elder, Yew, and Holly, have generally edible berries, much eaten by birds. The winged seeds or fruits characterise the great forest trees.

TREES, SHRUBS, AND CLIMBING SHRUBS NATIVE OR NATURALISED IN BRITAIN.

	Seed or Fruit.			
	Edible.	Hairy.	Winged.	Hooked.
Clematis vitalba		×		
Berberis vulgaris	×			
Lime (*Tilia Europœa*) . .			×	
Maple (*Acer*)			×	
Spindle Tree (*Euonymus*) .	×			
Buckthorn (*Rhamnus*) . .	×			
Sloe (*Prunus*).	×			
Rose (*Rosa*)	×			
Apple (*Pyrus*).	×			None.
Hawthorn (*Cratœgus*) . .	×			
Medlar (*Mespilus*) . . .	×			
Ivy (*Hedera*)	×			
Cornel (*Cornus*)	×			
Elder (*Sambucus*). . . .	×			
Guelder Rose (*Viburnum*) .	×			
Honeysuckle (*Lonicera*). .	×			
Arbutus (*Arbutus*) . . .	×			

	Seed or Fruit.			
	Edible.	Hairy.	Winged.	Hooked.
Holly (*Ilex*)	×			
Ash (*Fraxinus*)			×	
Privet (*Ligustrum*) . . .	×			
Elm (*Ulmus*)			×	
Hop (*Humulus*)			×	
Alder (*Alnus*).				
Birch (*Betula*).			×	
Hornbeam (*Carpinus*) . .			×	None.
Nut (*Corylus*)	×			
Beech (*Fagus*).	×			
Oak (*Quercus*).	×			
Willow (*Salix*)		×		
Poplar (*Populus*)		×		
Pine (*Pinus*)			×	
Fir (*Abies*)			×	
Yew (*Taxus*)	×			

6. Or let us take one natural order. That of the **Roses** is particularly interesting. In the genus *Geum* the fruit is provided with hooks; in *Dryas* it terminates in a long feathered awn, like that of **Clematis**. On the other hand, several genera have edible fruits ; but it is curious that the part of a plant which becomes fleshy, and thus tempting to animals, differs considerably in the different genera. In the **Blackberry**, for instance, and in the **Raspberry**, the carpels constitute the edible portion. When we eat a Raspberry we strip them off, and leave the receptacle (the white fleshy part) behind ; while in the Strawberry the receptacle constitutes the edible portion—the carpels are small, hard, and closely surround the seeds. In these genera the

sepals are situated below the fruit. In the Rose, on the contrary, the peduncle is swollen and inverted, so as to form a hollow cup, in the interior of which the carpels are situated. Here you will remember that the sepals are situated above, not below, the fruit. Again, in the **Pear** and **Apple** it is the ovary which constitutes the edible part of the fruit, and in which the pips are imbedded. At first sight the fruit of the **Mulberry**—which, however, belongs to a different family—closely resembles that of the Blackberry. In the Mulberry, however, it is the sepals which become fleshy and sweet.

7. The next point is that seeds should be in a spot suitable for their growth. In most cases the seed lies on the ground, into which it then pushes its little root. In plants, however, which live on trees the case is not so simple, and we meet with some curious contrivances. Thus, the **Mistletoe**, as we all know, is parasitic on trees. The fruits are eaten by birds, and the droppings often therefore fall on the boughs; but if the seed was like that of most other plants it would soon fall to the ground, and consequently perish. Almost alone among English plants, it is extremely sticky, and thus adheres to the bark.

8. Another very interesting genus, again, of the same family is *Myzodendron* (fig. 80), a Fuegian species allied to the Mistletoe, and parasitic on the Beech. Here the seed is not sticky, but is provided with four flattened flexible appendages. These

catch the wind, and thus carry the seed from one tree to another. As soon, however, as they touch

Fig. 80.—Seed of MYZODENDRON.

any little bough the arms twist round it and there anchor the seed.

9. In many plants which live as parasites on trees the seeds are extremely numerous and minute

Their great numbers increase the chance that the wind may waft some of them to the trees on which they grow; and as they are then fully supplied with nourishment they do not require to carry any store with them. Moreover their minute size is an advantage, as they are carried into any little chink or cranny in the bark; while a larger or heavier seed, even if borne against a suitable tree, would be more likely to drop off.

Fig. 81.—A Brazilian CARDAMINE.
a a, ordinary pods; *b*, subterranean pods.

VI.

1. Even among terrestrial species there are many cases in which plants are not contented simply

to leave their seeds on the surface of the soil, but actually sow them in the ground.

Thus in the **Subterranean Clover**, one of our rarer kinds, only a few of the florets become perfect flowers, the others form a rigid pointed head which at first is turned upwards, and as their ends are close together, constitute a sort of spike. At first, I say, the flower-heads point upwards like those of other clovers, but as soon as the florets are fertilised, the flower-stalks bend over and grow downwards, forcing the flower-head into the ground, an operation much facilitated by the peculiar construction and arrangement of the imperfect florets. The florets are, as Darwin has shown, no mere passive instruments. So soon as the flower-head is in the ground they begin, commencing from the outside, to bend themselves towards the peduncle, the result of which of course is to drag the flower-head further and further into the ground. In most clovers each floret produces a little pod. This would in the present species be useless; many young plants growing in one place would jostle and starve one another. Hence we see another obvious advantage in the fact that only a few florets perfect their seeds.

2. I have already alluded to our **Cardamines**, the pods of which open elastically and throw their seeds some distance. A Brazilian species (fig. 81), besides the usual long pods (fig. 81, *a a*), produces

also short pointed ones (fig. 81, *b b*), which it buries in the ground.

In the case of the **Ground-nut** of the West Indies the flower is yellow and resembles that of a pea, but has an elongated calyx, at the base of which, and close to the stem, is the ovary. After the flower has faded, the young pod, which is oval, pointed, and very minute, is carried forward by the growth of the stalk, which becomes two or three inches long and curves downwards so as generally to force the pod into the ground. If it fails in this, the pod does not develop, but soon perishes; on the other hand, as soon as it is underground the pod begins to grow and develops two large seeds.

3. In a South European species of **Vetch** (fig. 82) there are two kinds of pods. One of the ordinary form and habit (*a*), the other (*b*), oval, pale, containing only two seeds borne on underground stems, and produced by flowers which have no corolla.

Again, a species of the allied genus *Lathyrus* (fig. 83) affords us another case of the same phenomenon.

There are many other species possessing the same faculty of burying their seeds, belonging moreover to very different families of plants.

4. Moreover, it is interesting that in several of these the subterranean pods differ from the usual and aërial form in being shorter and containing fewer seeds. The reason of this is, I think, obvious. In the ordinary pods the number of seeds of course

increases the chance that some will find a suitable place. On the other hand, the subterranean ones

Fig. 82.—VETCH (*Vicia amphicarpa*).
a a, ordinary pods; *b b*, subterranean pods.

are carefully sown, as it were, by the plant itself. Several seeds together would only interfere with

one another, and it is therefore better that one or two only should be produced.

Fig. 83.—PEA (*Lathyrus amphicarpos*).
a, ordinary pods; *b*, subterranean pods.

5. In the **Crane's Bills** the fruit is a capsule which opens elastically, in some species throwing the

seeds to some little distance. The seeds themselves are more or less spindle-shaped, hairy, and produced into a twisted hairy awn, as shown in fig. 84. The number of spiral turns in the awn depends upon the amount of moisture; and the seed may

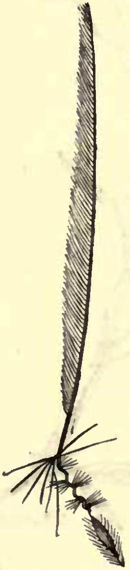


Fig. 84.—Seed of CRANE'S BILL.

thus be made into a very delicate hygrometer, for if it be fixed in an upright position, the awn twists or untwists according to the degree of moisture, and its extremity thus may be so arranged as to move up and down like a needle on a register. It is also affected by heat. Now, if the awn were

fixed, it is obvious that during the process of untwisting the seed itself would be pressed downwards, and this mechanism thus serves actually to bury the seed.

6. If a seed of this plant is laid on the ground, it remains quiet as long as it is dry ; but as soon as it is moistened—*i.e.*, as soon as the earth becomes in a condition to permit growth—the outer side of the awn contracts, and the hairs surrounding the seed commence to move outwards, the result of which is gradually to raise the seed into an upright position with its point on the soil. The awn then commences to unroll, and consequently to lengthen itself upwards, and it is obvious that as it is covered with reversed hairs, it will probably press against some blade of grass or other obstacle, which will prevent its moving up, and will therefore tend to drive the seed into the ground. If then the air becomes dryer, the awn will again roll up, when from the position of the hairs the feathery awn can easily slip downwards, and will therefore not affect the seed. When moistened once more, it will again force the seed further downwards, and so on until the proper depth is obtained. One of the **Mountain Anemones** again has essentially the same arrangement, though belonging to a widely separated order.

7. A still more remarkable instance is afforded by a beautiful South European grass, *Stipa pennata* (fig. 85). The actual seed is small, with a sharp

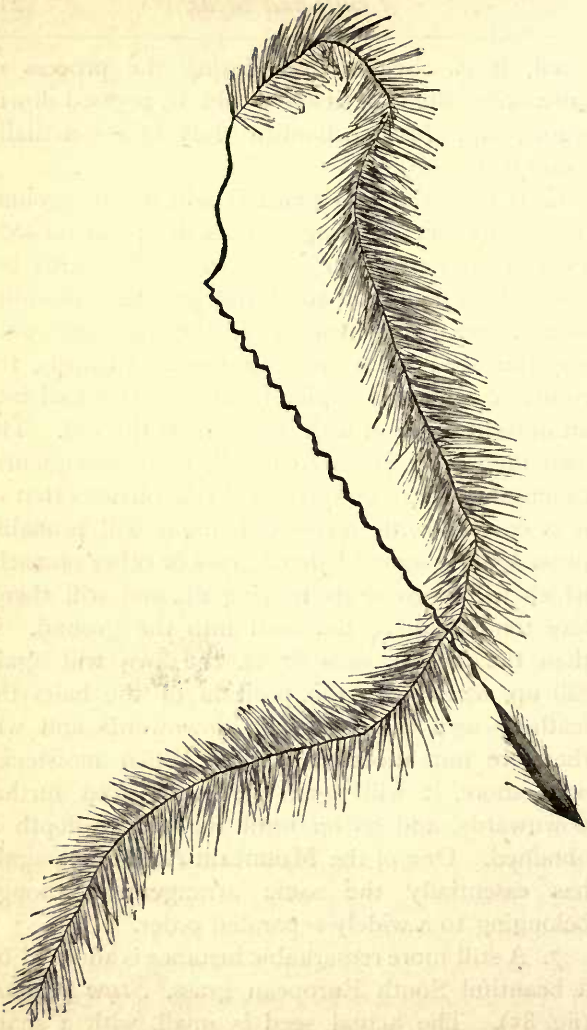


Fig. 85.—Seed of STIPA, a South European Grass. (Natural size.)

point, and stiff, short hairs pointing backwards. The posterior end of the seed is produced into a fine twisted corkscrew-like rod, which is followed by a plain cylindrical portion, attached at an angle to the corkscrew, and ending in a long and beautiful feather, the whole being more than a foot in length. The long feather, no doubt, facilitates the dispersion of the seeds by wind; eventually, however, the seeds sink to the ground, which they tend to reach (the feather being the lighter portion), point downwards. Frank Darwin considers that the seed remains in that position as long as it is dry, but if a shower comes on, or when the dew falls, the spiral unwinds, and if, as is most probable, the surrounding herbage or any other obstacle prevents the feathers from rising, the seed itself is forced down and so driven by degrees into the earth. I have suggested, on the contrary, that the wind acting on the feather gradually drives the seeds into the ground.

VII.

1. I have already mentioned several cases in which plants produce two kinds of seeds, or at least of pods, the one being adapted to burying itself in the ground. There is, in addition, a North African species of **Corydalis** which produces two kinds of seeds (fig. 86), one somewhat flattened, short and

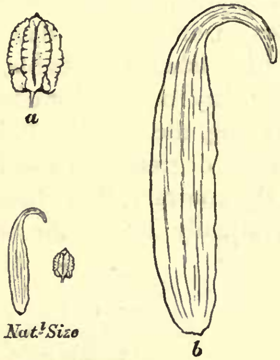


Fig. 86.—Seeds of CORYDALIS.

broad, with rounded angles; the other elongated, and hooked. In this case the hook in the latter form perhaps serves for dispersion.

2. Our common **Lesser Hawkbit** (fig. 76, *b*) also possesses, besides the fruits with the well-known feathery crown, others which are destitute of such

a provision, and which probably therefore are intended to take root at home.

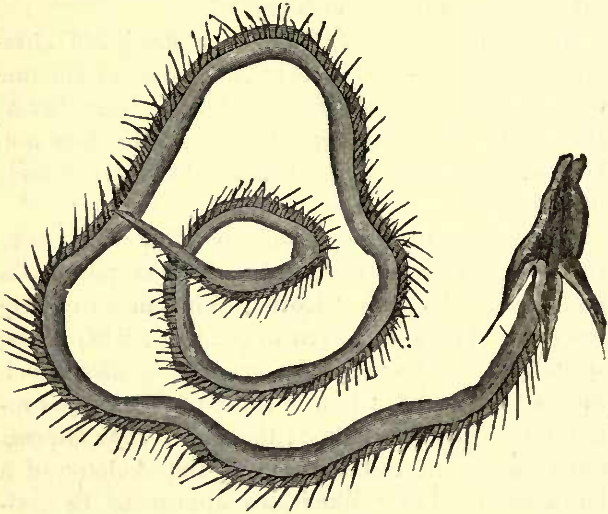
Mr. Drummond has described a species of *Alismaceæ* which has two sorts of seed-vessels ; the one produced from large floating flowers, the other at the end of short submerged stalks. He does not, however, describe either the seeds or seed-vessels in detail.

3. Before concluding I will say a few words as to the very curious forms presented by certain seeds and fruits. The pods of Lotus, for instance, quaintly resemble a bird's foot, even to the toes ; whence the specific name of one species, *ornithopodioides*, which means "like a bird's foot"; those of *Hippocrepis* remind one of a horseshoe; those of *Trapa bicornis* have an absurd resemblance to the skeleton of a bull's head. These likenesses appear to be accidental, but there are some which probably are of use to the plant. For instance, there are two species of *Scorpiurus* (fig. 87), the pods of which lie on the ground, and so curiously resemble, the one (fig. 87,*a*) a centipede, the other (fig. 87, *b*) a worm or caterpillar, that it is almost impossible not to suppose that the likeness must be of some use to the plant.

The pod of a kind of *Biserrula* (fig. 88) also has a striking resemblance to a flattened centipede; while the seeds of *Abrus*, both in size and in their very striking colour, mimic a small beetle, *Artemis circumusta.*

4. Mr. Moore has recently called attention to other

a



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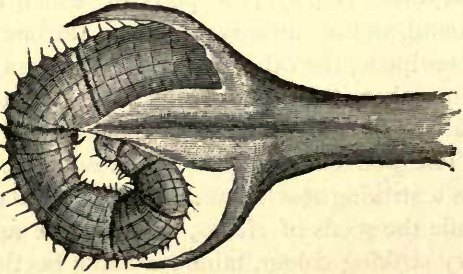

Fig. 87.

a, pod of *Scorpiurus subvillosa*; *b*, pod of *Scorpiurus vermiculata.*

cases of this kind. Thus the seed of *Martynia diandra* much resembles a beetle with long antennæ; several species of **Lupins** have seeds much like spiders, and those of a gourdlike plant,* mimic a piece of dry twig. In the common castor oil plants (fig. 89), though the resemblance is not so

Fig. 88.—Pod of BISERRULA.

Fig. 89.—Seed of CASTOR OIL PLANT.

close, still at a first glance the seeds might readily be taken for beetles or ticks. In many plants allied to **Euphorbia** plants, as, for instance, in **Jatropha** (fig. 90), the resemblance is even more striking. The seeds have a central line resembling the space between the elytra, or wing cases, dividing and

* *Dimorphochlamys.*

slightly diverging at the end, while between them the end of the abdomen seems to peep; at the anterior end the seeds possess a small lobe, which mimics the head or thorax of the insect, and which even seems specially arranged for this purpose; at least it would seem from experiments made at Kew that the removal of this little lobe does not injure the seed.

5. These resemblances might benefit the plant in one of two ways. If it be an advantage to the plant that the seeds should be swallowed by birds,

Fig. 90.—Seed of JATROPHA.

their resemblance to insects might lead to this result. On the other hand, if it be desirable to escape from grain-eating birds, then the resemblance to insects would serve as a protection. We do not, however, yet know enough about the habits of these plants to solve this question.

6. Indeed, as we have gone on, many other questions will, I doubt not, have occurred to you, which we are not yet in a position to answer. Seeds, for instance, differ almost infinitely in the sculpturing

of their surface. I shall have failed woefully in my object if I leave you with the impression that we know all about seeds. On the contrary, there is not a fruit or a seed, even of one of our commonest plants, which would not amply justify and richly reward the most careful study.

7. In this, as in other branches of science, we have but made a beginning. We have learnt just enough to perceive how little we know. Our great masters in natural history have immortalised themselves by their discoveries, but they have not exhausted the field; and if seeds and fruits cannot vie with flowers in the brilliance and colour with which they decorate our gardens and our fields, still they surely rival them in the almost infinite variety of the problems which they present to us, the ingenuity, the interest, and the charm of the beautiful contrivances which they offer for our study and our admiration.

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